TECHNICAL OPERATIONS INCORPORATED

THE PROBABLE FALLOUT THREAT OVER THE CONTINENTAL UNITED STATES

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CHAPTER 1

INTRODUCTION

Many hypothetical nuclear attacks on the United States have been postulated by responsible agencies during the past several years, and an analysis of the material damage and probable casualties from blast, thermal, and radiation effects carried out in considerable detail.* Although the over-all results in terms of predicted casualties for a given level of attack seem to agree reasonably well among the different studies, the particular targets selected, weapon criteria, assumed wind conditions, and fallout model used differ widely from one agency which has made studies to the next. Occasionally some of the rationale behind these four major inputs necessary to the development and analysis of any possible area threat is presented or implied, but more often than not the basic reasoning and logical development of the input data for the postulated attacks analyzed is not available in the unclassified literature, if at all.

One might argue that since we can never really know ahead of time what targets and weaponage the enemy would select if an attack is launched, nor can we possibly know what the wind conditions will be at that time, any arbitrary selection of targets, weapons, fallout model and winds is probably as good as any other in developing a full scale attack and analyzing the consequences in terms of casualties and the radiation hazard. There is certainly some truth in this philosophy. The uncertainties are indeed very large, and conclusions based on such studies, even a large number of them, must of necessity be rather general and suggestive rather than specific and definitive.

After a careful study of the inputs, however, it is our firm belief that meaningful priorities can be established among the various possible military and industrial targets, and that the size and number of weapons assigned to the different targets can be logically determined in light of: (1) the desired damage, (2) the degree to which the targets have been hardened, and (3) the probable accuracy

* Hawkins, M.B., "Progress Report: Summary of Problems Relating to Local Fallout Contamination of Water Supplies", Appendix B - "Estimate of the Range of Contamination Levels Resulting From Various Attacks", University of California, Civil Defense Research Project, Contract No. CD-SR-58-40, February 24, 1959.

of the delivery system. In addition, although the integrated upper wind direction and speed is by no means constant, there are very definite preferred directions depending on the season and location, and in certain areas of the country the wind reliability is high enough to allow realistic planning on the basis of the annual and mean seasonal wind direction and speed. Finally, it is believed that even though sizeable differences exist between the fallout contours predicted by one model as opposed to another (for any specified set of wind conditions), the model used in this study is an accurate enough representation to the true fact so that meaningful and useful conclusions based on its predictions regarding probable fallout levels over the various parts of the country can be drawn with confidence, and realistic Civil Defense plans made on the basis of these predictions.

The purpose of this report is first to present in detail, a basis of selection and development of the four major inputs required for a countrywide fallout analysis. These inputs are:

1) Target selection
2) Weapon criteria
3) Wind conditions
4) Fallout model

Secondly, two techniques are presented for combining the fallout levels from different weapons in a multi-weapon attack where significant overlap of the contours exists. And, finally, the probable fallout threat from both a military and a combined military and industrial attack on the U. S. is developed and analyzed for two characteristic seasonal wind conditions.

Chapter 2 is divided into three sections. The first section deals with military targets, describing the priority categories for the Air Force and Navy bases considered, and the size and number of weapons required for a very high probability of complete destruction of these facilities based on the assumed accuracy of the enemy's missile delivery systems. The second section discusses the industrial, governmental, and power resource targets considered, together with priority classifications for each and the weapon criteria selected. The target lists and megatonnage thus selected are compared against those of other hypothetical attacks which have been recently publicized. The final section presents two specific attack patterns and estimates the casualties that would be expected to occur countrywide depending on the degree of shelter protection provided.

Chapter 3 presents an analysis of the upper air fallout winds over the United States based on a study by the Weather Bureau in which data collected over a five-year period at 41 stations in the country were surveyed. Since the size and shape of fallout patterns are dependent on the integrated wind speed and wind shear condition, the feasibility of dividing the country into just two wind belts depending on the season was investigated. Such a scheme proved reasonable and was adopted. In a similar manner, the mean seasonal wind directional reliability was investigated and the country divided into areas of good, fair, or poor reliability, again depending on the season. Finally, the mean annual wind direction was studied to determine when and where, if at all, it might be used as a reliable indicator in delineating probable high and low fallout areas.

Chapter 4 presents a detailed description of the fallout model originally developed by Technical Operations, Inc. for fallout studies carried out by the Operations Research Office of John Hopkins University. The basic assumptions are reviewed in the light of the most recent knowledge available in the unclassified literature, and a simplified shorthand method for calculating 2-day dose contours is presented which allows a set of fallout contours to be drawn in a matter of minutes. This model was used to develop 2-day dose contours for the mean seasonal winds shown in Chapter 3. The model was also compared against the idealized, scaled contours used by OCDM in recent operation alerts for both low and high wind speeds.

Chapter 5 describes two methods which were developed to shorten the time required to analyze the cumulative fallout over the U. S. from a full scale attack. The first method is called the Photographic Density Analog Technique and consists of making a set of semi-transparent contours for a given weapon size and wind speed in which the optical density for the various contours is the analog of the 2-day dose level. The method is believed capable of rapidly assessing the countrywide radiological situation with an accuracy of better than a factor of two from an attack involving several hundred weapons. This method was not used, however, to develop the radiological situations presented in Chapter 6, since a second method called the Layered (paper) Analog Technique proved to be easier and simpler for the very limited number of countrywide radiological situations actually analyzed. In this second method, layers of paper are used as the analog for the 2-day dose levels and the number of sheets are "counted" by a densitometer which measures the amount of light passing through the stack at each point.

Chapter 6 presents a set of maps of the OCDM regions showing the predicted 2-day dose levels for two levels of attack (a 1840-MT military attack and a 4080 MT combination military and industrial attack), and two different wind conditions (mean seasonal winter and summer winds). These fallout levels are statistically summarized and quantitatively compared with other analyses reported in the literature. Sizeable discrepancies between the different estimates of the radiological situation were found to exist, and an attempt made to reconcile them by uncovering the basic factors which appear to be responsible for much of the discrepancy.

In summary, this report is an attempt to develop a realistic countrywide fallout threat, giving considerable detail on the background and rationale associated with the necessary input information, and present the results in a form readily usable by Civil Defense planners and organizations.

CHAPTER 2

MILITARY AND INDUSTRIAL TARGETS

2.1 MILITARY TARGETS

To determine the relative importance of U. S. military bases in terms of their contribution to the nation's existing and future over-all retaliatory and defensive potential, a study was made of the bases within the continental United States. It was assumed that a nuclear attack on the U. S. within the next few years will combine manned bombers and missiles, both of which have the capability of delivering nuclear weapons with effective ranges of 6000 or more miles.

Since the Army's role within the United States is not one of retaliation or air defense, Army bases have not been included in the military target list. Of the 159 military bases listed, 114 are Air Force Bases. The remaining 45 are Naval Air Stations and other Navy Bases.

2.1.1 Air Force Priority Categories

From the study it was apparent that the Air Force Bases may be divided into four priority categories. Missile bases have the highest priority. At the present time there are 21 authorized and identified missile bases. Only four of these are now operational and none are hardened as yet. During the next five years, however, two of the operational and all of the projected bases will be hardened to withstand at least 25 psi and, in most cases, to 100 psi overpressure or possibly more.

Until such time as the above missile launching sites are armed, our major deterrent force consists of Strategic Air Command bombers. The present force of approximately 1400 B-47's and more than 600 B-52's is equipped for high altitude mid-air refueling and is thus capable of striking enemy targets with nuclear weapons anywhere on the globe. These aircraft (and the initial squadrons of Mach 2, B-58 bombers) are deployed over 56 bases within the 48 states. Those bases not already included in the missile site tabulation (18) are listed as first priority targets. (Some SAC training bases are listed in the second or third priority.)

The direct retaliatory forces of the Air Defense Command and the SAGE centers which direct their operations are considered second priority targets because they would have to be destroyed by an enemy missile force before such an enemy would risk sending the bombers that he might wish to use for destroying our industrial facilities. Major transportation bases are also available for defense and are, therefore, included in this group.

All other major Air Force tactical, supply, transportation and research facilities have been placed in the third priority. While these facilities do not ordinarily house immediate offensive or defensive weapons they can readily be used for alternate emergency landing fields and their resources would be vital in a prolonged conflict (i.e., more than a day or two).

Table 2.1 tabulates the Air Force facilities with their classification.

TABLE 2.1

TARGET PRIORITIES FOR AIR FORCE BASES

Types of Facilities	Symbol (Priority Designation)	Number of Bases	Remarks
Intercontinental Ballistic Missiles (Atlas, Titan, Minuteman)	A_0	19	Not yet armed or hardened, but expected to be in the near future. By 1965 these missiles will constitute half our striking force and will be far less vulnerable than bomber bases.
Strategic Air Command	A_1	38	Currently the Number One retaliatory force. With its aerial tankers, it can deliver nuclear weapons within dozens of feet of any target on the globe.
Air Defense Command Semi Automatic Ground Environment Control Centers.	A_2	36	Major defense against attack by manned bombers and subsonic missiles.
Air Materiel Command Tactical Air Command Air Research and Development Command	A_3	21	Major logistic and research centers (Alternate airfields, supplies, and equipment.)
TOTAL		114	

2.1.2 Navy Priority Categories

The three largest naval offensive capability concentrations in the continental United States have been assigned first priority. As noted below there are not, and are not likely to be, provisions for hardening these bases against enemy attack so that these three installations (New London Submarine Headquarters, Portsmouth Navy Yard, and Norfolk Navy Base) could each be destroyed by a single 5-MT weapon. They are of prime retaliatory importance both because of their Polaris submarine and large carrier bomber complements. The submarines would, of course, have to cruise some distance before their missiles could reach enemy targets.

The major Naval Air Stations have a significant offensive as well as defensive capability. The Navy twin jet carrier and land-based bombers, A3D, can carry at least one of the largest nuclear bombs and, with in-flight refueling reach any enemy target from their continental U. S. bases. The A3D (and its Air Force counterpart, the B-66) has performance characteristics—speed, service ceiling, bomb load, and range with in-flight refueling—superior in many ways to those of the Air Force B-47. While the A3D was designed for service aboard such large carriers as the Essex, Forrestal and Midway, a sizeable number are quartered at some major Naval Air Stations. These facilities have been designated second priority.

All other major Navy fighter plane, fighting ship, and supply facilities have been designated third priority.

Table 2.2 tabulates the Navy facilities with their classifications.

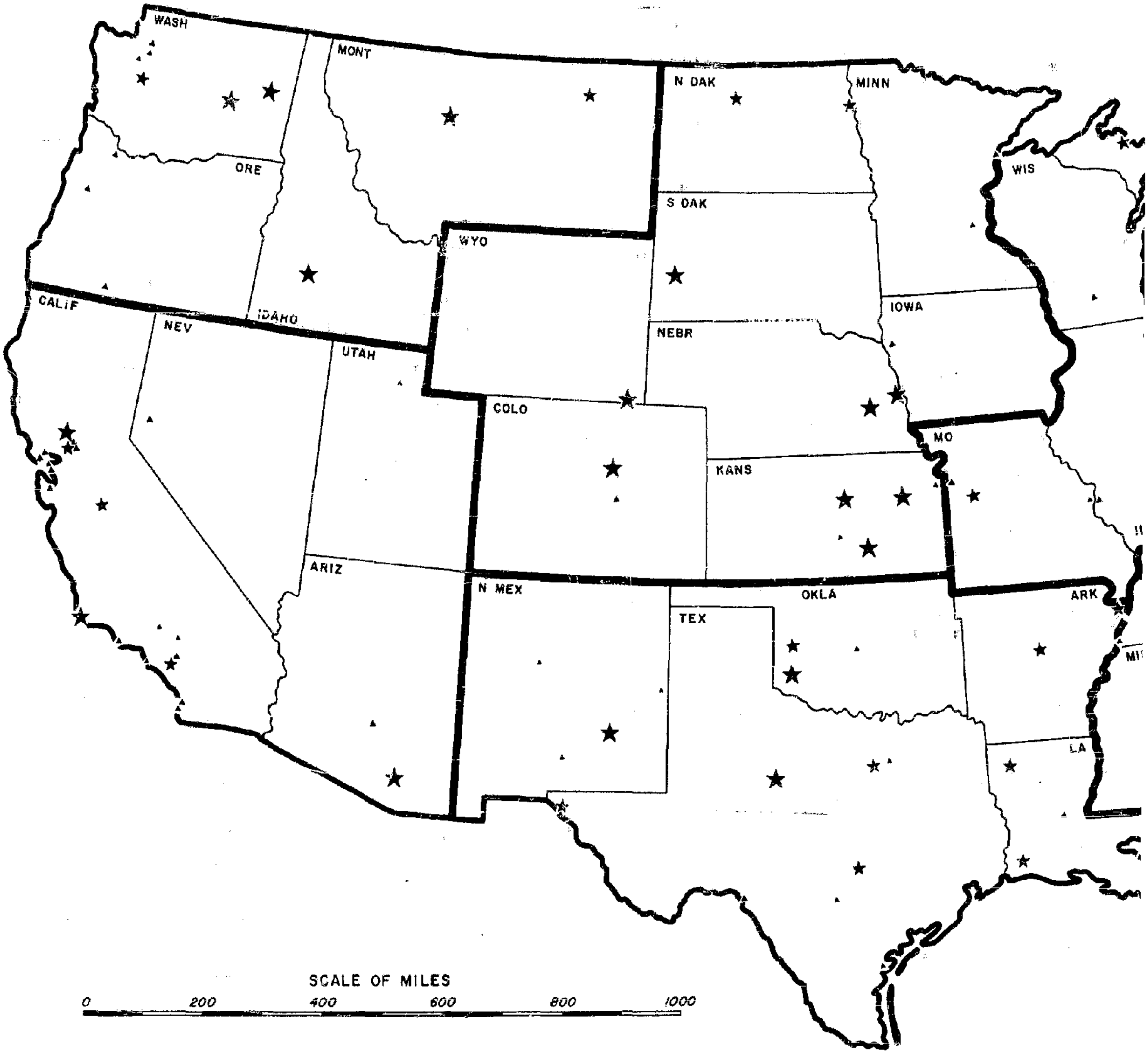
TABLE 2.2

TARGET PRIORITIES FOR NAVY BASES

Types of Facilities	Symbol (Priority Designation)	Number of Bases	Remarks
Submarine Headquarters Carrier Headquarters	N_1	3	Major Navy retaliatory forces. When at sea, these forces can deliver nuclear weapons to any target on the globe.
Naval Air Stations (Major)	N_2	15	Nuclear bombers comparable in performance, but fewer per base than Air Force A_1 bases. Defensive fighter airplanes comparable to those at Air Force A_2 bases.
Naval Air Stations Navy Yards	N_3	27	Major naval facilities comparable in logistic importance to Air Force A_3 bases.
TOTAL		45	

2.1.3 Military Target Locations, Identification, Priorities and Assigned Weaponage

Figure 2.1 shows the location of, and Table 2.3 lists the details of, each of the 159 military targets in the continental United States. There is at least one military target in every state except Kentucky and West Virginia. The greatest concentration of targets is the group of six in the San Francisco-Oakland-San Jose area. In general, military targets are distributed more uniformly around the country than is population or industrial capability.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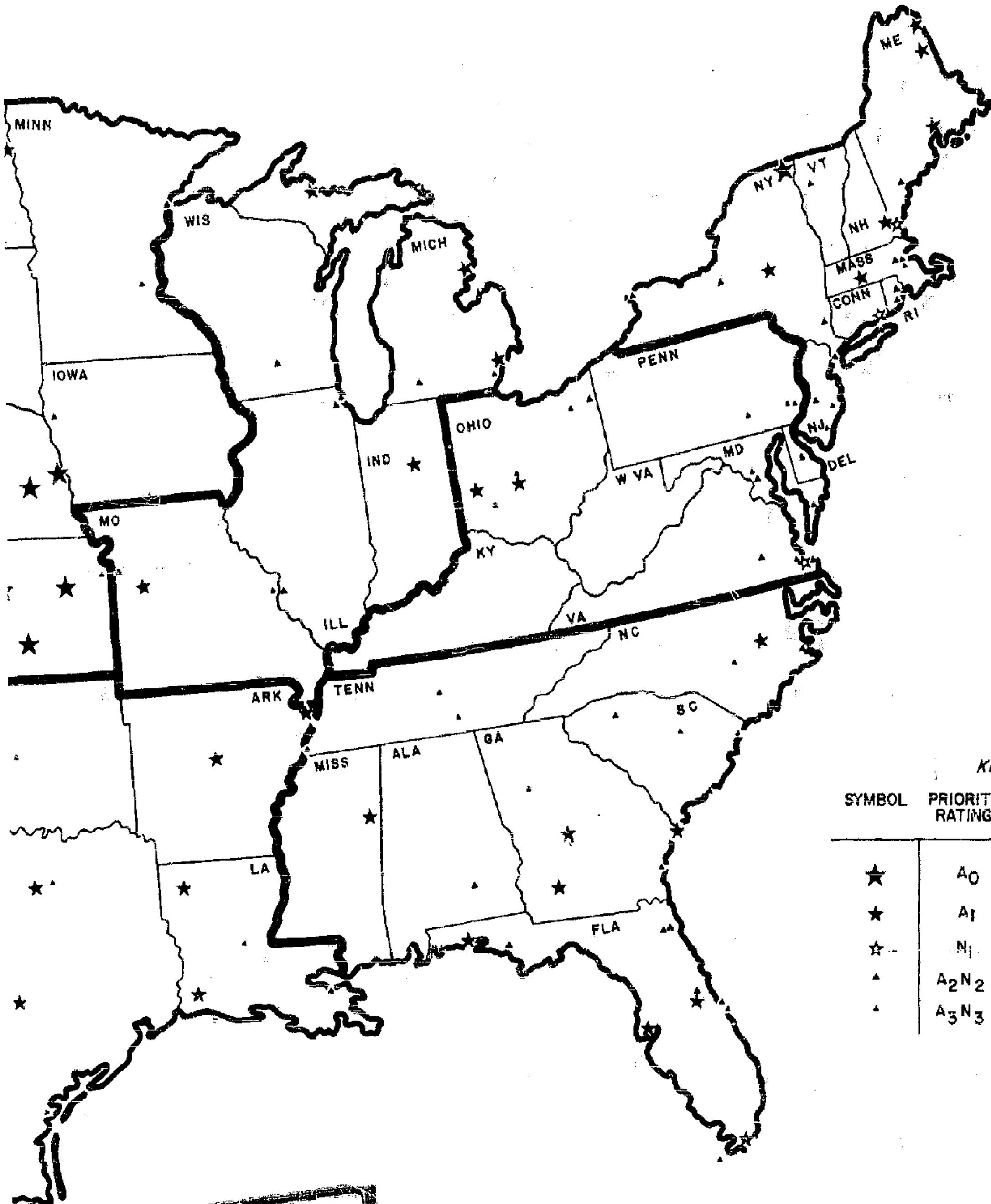


KEY

SYMBOL	PRIORITY RATING	NUMBER OF TARGETS
★	A_0	19
★	A_1	38
☆	N_1	3
▲	A_2N_2	51
▴	A_3N_3	48
		TOTAL 159

Fig. 2.1 Location of Military Targets in the United States

TABLE 2.3

UNITED STATES MILITARY TARGETS
(Arranged by OCDM Regions and States)

Region	State	Location	Target Name	Activities	Designation and Priority	Assigned Weaponage* (in Megatons)
	Conn.	New London	NB	Submarine Hq.	N_1	5
	Me.	Bangor	Dow AFB	SAC	A_1	15
		Brunswick-Topsham	NAS	NAS, SAGE	N_2	5
		Limestone	Loring AFB	SAC	A_1	15
		Presque Isle	AFB	SAC, Snark	A_1	15
	Mass.	Bedford	Laurence G. Hanscom Field	ARDC	A_2	5
		Boston	Navy Yard	Navy	N_2	5
		Chicopee Falls	Westover AFB	SAC	A_1	15
		Falmouth	Otis AFB	ADC	A_2	5
		Weymouth	NAS	NAS	N_3	5
	N. H.	Portsmouth SW	Pease AFB	SAC	A_1	15
OCDM 1		Portsmouth NE	Navy Yard	Navy	N_1	5
	N. J.	Atlantic City	NAS	NAS	N_3	5
		Lakehurst	NAS	NAS	N_3	5
		Wrightstown	McGuire AFB	MATS, SAGE	A_2	5
	N. Y.	Brooklyn	Navy Yard	Navy	N_2	5
		Newburgh	Stewart AFB	ADC, SAGE	A_2	5
		Niagara Falls	Municipal Airport, NAS	ADC, NAS	A_2	5
		Plattsburgh	AFB	Atlas, SAC	A_0	40
		Rome	Griffiss AFB	SAC, AMC	A_1	15
		Syracuse	Hancock Field	ADC, SAGE	A_2	5
		Westhampton Beach	Suffolk Co. AFB	ADC	A_2	5
	R. I.	Newport	NB	Navy	N_3	5
		Quonset Point	NAS	NAS	N_2	5
	Vt.	Winooski	Ethan Allen AFB	ADC	A_2	5
Region Total - 25 Targets						220
	Del.	Dover	AFB	MATS, SAC Ten	A_2	5
	D. C.	Washington	Bolling AFB, Anacostia NAS	HQ-USAF, NAS	A_3	5
	Ky.	—	—	—	—	—
	Md.	Camp Springs	Andrews AFB	AF Hq., SAC Ten	A_2	5
	Ohio	Akron	NAS	NAS	N_3	5
		Columbus S	Lockbourne AFB	SAC	A_1	15
		Columbus E	NAS	NAS	N_3	5
		Dayton	Wright-Patterson AFB	SAC, AMC	A_1	15
OCDM 2		Wilmington	Clinton Co. AFB	CONAC, SAC Ten	A_2	5
		Youngstown	Municipal Airport	ADC	A_2	5
	Pa.	Middletown	Olmsted AFB	AMC	A_3	5
		Philadelphia	Navy Yard	Navy	N_3	5
		Willow Grove	NAS	NAS	N_3	5
	Va.	Chincoteague	NAS	NAS	N_3	5
		Fort Lee	AFB	SAGE	A_2	5
		Hampton	Langley AFB	TAC	A_3	5
		Norfolk	NB	Navy	N_1	5
		Oceana	NAS	NAS	N_2	5
	W. Va.	—	—	—	—	—
Region Total - 17 Targets						105

* See Section 2.1.4 for development of weapon criteria.

(Cont'd)

TABLE 2.3 (Cont'd)

UNITED STATES MILITARY TARGETS
(Arranged by OCDM Regions and States)

Region	State	Location	Target Name	Activities	Designation and Priority	Assigned Weaponage* (in Megatons)
	Ala.	Mobile	Brookley AFB	AMC	A_3	5
		Montgomery	Gunter AFB	AU, SAGE	A_2	5
	Fla.	Cape Canaveral	Proving Ground	Missile Test	A_3	5
		Cecil Field	NAS	NAS	N_2	5
		Cocoa Beach	Patrick AFB	ARDC	A_3	5
		Homestead	AFB	SAC	A_1	15
		Jacksonville	NAS	NAS	N_2	5
		Key West	NAS	NAS	N_3	5
		Orlando	McCoy AFB	SAC	A_1	15
		Panama City	Tyndall AFB	ADC	A_2	5
		Pensacola	NAS	NAS	N_3	5
		Sanford	NAS	NAS	N_2	5
		Tampa	MacDill AFB	SAC	A_1	15
		Valparaiso	Eglin AFB	SAC, ARDC	A_1	15
OCDM 3	Ga.	Albany	Turner AFB	SAC	A_1	15
		Atlanta	NAS (Dobbins AFB)	NAS	N_3	5
		Brunswick	NAS	NAS	N_3	5
		Savannah	Hunter AFB	SAC	A_1	15
		Warner Robins	Robins AFB	SAC, AMC	A_1	15
	Miss.	Columbus	AFB	SAC	A_1	15
	N. C.	Cherry Point	NAS	NAS	N_2	5
		Fayetteville	Pope AFB	TAC	A_3	5
		Goldsboro	Seymour Johnson AFB	SAC, TAC	A_1	15
	S. C.	Greenville	Donaldson AFB	MATS	A_2	5
		Myrtle Beach	AFB	TAC	A_3	5
		North Charleston	Charleston AFB, NY	MATS, Navy Yard	A_2	5
		Sumter	Shaw AFB	TAC	A_3	5
	Tenn.	Memphis	NAS	NAS	N_3	5
		Smyrna	Sewart AFB	TAC	A_3	5
		Tullahoma	Arnold Eng. Dev. Cntr.	ARDC	A_3	5
Region Total - 30 Targets						240
	Ill.	Belleville	Scott AFB	MATS, ADC	A_2	5
		Glenview	NAS	NAS	N_3	5
		Park Ridge	O'Hare Intl. Airport	ADC	A_2	5
	Ind.	Peru	Bunker Hill AFB	SAC	A_1	15
	Mich.	Fort Custer	Custer AF Stn	ADC, SAGE	A_2	5
		Grosse Isle	NAS	NAS	N_3	5
OCDM 4		Marquette (Gwinn)	K I Sawyer AFB	SAC, ADC, SAGE	A_1	15
		Mount Clemens	Selfridge AFB	SAC, ADC	A_1	15
		Oscoda	Wurtsmith AFB	SAC, ADC	A_1	15
		Sault Sainte Marie (Kinross)	Kincheloe AFB	SAC, ADC	A_1	15
	Mo.	Grandview	Richards-Gebaur AFB	ADC	A_2	5
		Knob Noster	Whiteman AFB	SAC	A_1	15
		St. Louis	NAS	NAS	N_3	5
	Wis.	Madison	Truax Field	ADC, SAGE	A_2	5
Region Total - 14 Targets						130

* See Section 2.1.4 for development of weapon criteria.

(Cont'd)

TABLE 2.3 (Cont'd)

UNITED STATES MILITARY TARGETS
(Arranged by OCDM Regions and States)

Region	State	Location	Target Name	Activities	Designation and Priority	Assigned Weaponage* (in Megatons)
	Ark.	Blytheville	AFB	SAC	A_1	15
		Jacksonville	Little Rock AFB	SAC	A_1	15
	La.	Alexandria	England AFB	TAC	A_3	5
		Bossier City	Barksdale AFB	SAC	A_1	15
		Lake Charles	Chennault AFB	SAC, ADC	A_1	15
		New Orleans	NAS	NAS	N_3	5
	N. M.	Alamogordo	Holloman AFB	ARDC	A_3	5
		Albuquerque	Kirtland AFB	ARDC	A_3	5
		Clovis	Cannon AFB	TAC	A_3	5
		Roswell	Walker AFB	Atlas, SAC	A_0	40
OCDM 5	Okla.	Altus	AFB	Atlas, SAC	A_0	40
		Burns Flat	Clinton Sherman AFB	SAC	A_1	15
		Oklahoma City	Tinker AFB	AMC	A_3	5
	Tex.	Abilene	Dyess AFB	Atlas, SAC	A_0	40
		Austin	Bergstrom AFB	SAC	A_1	15
		Corpus Christi	NAS	NAS	N_3	5
		Dallas	Hensley Field NAS	NAS	N_3	5
		Del Rio	Laughlin AFB	SAC Ten	A_2	5
		El Paso	Biggs AFB	SAC	A_1	15
		Fort Worth	Carswell AFB	SAC	A_1	15
		San Antonio	Randolph AFB	ATC	A_3	5
Region Total - 21 Targets						290
	Colo.	Colorado Springs	Ent AFB	ADC	A_2	5
		Denver	Lowry AFB; Buckley NAS	Titan, ATC; NAS	A_0	40
	Iowa	Sioux City	AFB	ADC	A_2	5
	Kan.	Hutchinson	NAS	NAS	N_3	5
		Olathe	NAS	NAS	N_3	5
		Salina	Schilling AFB	Atlas, SAC	A_0	40
		Topeka	Forbes AFB	Atlas, SAC	A_0	40
		Wichita	McConnell AFB	Titan, SAC	A_0	40
OCDM 6	Minn.	Duluth	Municipal Airport	ADC, SAGE	A_2	5
		Minneapolis	NAS	NAS	N_3	5
	Neb.	Lincoln	AFB; NAS	Atlas, SAC; NAS	A_0	40
		Omaha	Offutt AFB	Atlas, SAC	A_0	40
	N. D.	Grand Forks	AFB	SAC, ADC, SAGE	A_1	15
		Minot	AFB	SAC, ADC, SAGE	A_1	15
	S. D.	Rapid City	Ellsworth AFB	Titan, SAC	A_0	40
	Wyo.	Cheyenne	Francis E. Warren AFB	Atlas, SAC	A_0	40
Region Total - 16 Targets						380

* See Section 2.1.4 for development of weapon criteria. (Cont'd)

TABLE 2.3 (Cont'd)

UNITED STATES MILITARY TARGETS
(Arranged by OCDM Regions and States)

Region	State	Location	Target Name	Activities	Designation and Priority	Assigned Weaponage* (in Megatons)
	Ariz.	Phoenix	Luke AFB	SAGE, TAC	A_2	5
		Tucson	Davis-Monthan AFB	Titan, SAC	A_0	40
	Calif.	Alameda	NAS	NAS	N_2	5
		Camarillo	Oxnard AFB	ADC	A_2	5
		Fairfield	Travis AFB	SAC, MATS	A_1	15
		Ignacio	Hamilton AFB	ADC	A_2	5
		Lompoc	Vandenberg AFB	All missiles	A_0	40
		Long Beach	NAS	NAS	N_3	5
		Marysville	Beale AFB	Titan, SAC, SAGE	A_0	40
		Merced	Castle AFB	SAC	A_1	15
		Miramar	NAS	NAS	N_2	5
OCDM 7		Muroc	Edwards AFB	ARDC	A_3	5
		Oakland	NAS	NAS	N_3	5
		Palo Alto	Moffett NAS	NAS	N_2	5
		Riverside	March AFB	SAC	A_1	15
		Sacramento E	Mather AFB	ATC	A_2	5
		Sacramento NE	McClellan AFB	AMC	A_3	5
		San Bernardino	Norton AFB	SAGE, AMC, SBAMA	A_2	5
		San Diego	NAS, NB	Navy	N_2	6
		Vallejo	Mare Island Naval Shipyard	Navy	N_2	5
		Victorville	George AFB	TAC	A_3	5
	Nev.	Reno	Stead AFB	SAGE, ATC	A_2	5
	Utah	Ogden	Hill AFB	AMC	A_3	5
Region Total - 23 Targets						250
	Idaho	Mountain Home	AFB	Titan, SAC	A_0	40
	Mont.	Glascow	AFB	SAC, ADC	A_1	15
		Great Falls	Malmstrom AFB	SAC, SAGE	A_0	40
	Ore.	Corvallis	Camp Adair	SAGE	A_2	5
		Klamath Falls	Kingsley Field	ADC	A_2	5
		Portland	International Airport	ADC	A_2	5
	Wash.	Everett	Paine AFB	ADC	A_2	5
OCDM 8 (except Alaska and Hawaii)		Moses Lake	Larson AFB	Titan, SAC, SAGE, MATS	A_0	40
		Seattle SW	Puget Sound NS	Navy	N_3	5
		Seattle NE	Sand Point NAS	NAS	N_3	5
		Spokane	Fairchild AFB	Atlas, SAC	A_0	40
		Tacoma	McChord AFB	SAC, SAGE, ADC	A_1	15
		Whidbey Field	NAS	NAS	N_2	5
Region Total - 13 Targets						225
Total of Eight Regions - 159 Targets					(Megatons) - (368 Weapons)	1,840

* See Section 2.1.4 for development of weapon criteria.

The functions and priorities of each base have been determined by the unclassified information available in early 1960. In some cases the classification is arbitrary.

Adjacent bases such as Bolling Air Force Base and Anacostia Naval Air Station in Washington, D. C., have been listed as single targets since they could be destroyed by a single properly aimed missile.

Not included in the above target list are the numerous Army, Navy and Air Force training centers or the small Air Defense Command stations.

Changing military requirements during the next five years will inevitably change some of the above priorities, but the Air Force appears to be locating new missile sites at present SAC bases so that an attack pattern on fixed sites is not likely to be significantly different from that illustrated and tabulated above. If, at some time in the future, a mobile missile system is adopted which uses part or all of either the rail or road net in the U. S., then the potential number of military ground zero locations would increase many times depending on the number of mobile missile units, their mode and area of operation, and the degree of enemy intelligence concerning their precise position at the time an attack is launched. Such a missile system is not likely to be operational within the next five years, and, therefore, has not been specifically considered in this study. It may well be, however, an integral part of our defense posture 5 to 10 years hence, and as such should be analyzed to see what the resulting fallout patterns from an attack on such a system might be.

2.1.4 Weapon Criteria

The military attack pattern seeks to achieve the following two objectives:

1) To knock out our immediate retaliatory capability.

2) To destroy our air defense capability.

The weapons used in the attack are assumed to be 5-MT surface bursts delivered by ICBM's. These conditions were chosen to take full advantage of the element of surprise inherent in a missile attack, and the limited tonnage that can be propelled by present day missiles. A 5-MT warhead is consistent with the payload

of presently designed ICBM's,* and since the number of delivery systems is believed to be more critical than the total weapon arsenal, the weapon allocation was made in accordance with delivery system economy. It should be mentioned, in addition, that using a single size weapon substantially reduces the effort required in developing fallout situation maps covering the U. S. for the different attack and wind conditions considered.

All military bases were placed into one of three categories depending on the degree to which they have been, or are assumed to be, hardened as shown in Table 2.4.

TABLE 2.4

VULNERABILITY OF MILITARY BASES

Category Designation	Peak over Pressure Required to Render Base and/or its Facilities Unusable (psi)	Type of Military Base Present	Future
1. Soft Site	6	Parked aircraft on any base; ships, and all other facilities and supplies (except runways) which have not been specifically hardened.	
2. Medium Hard Site	25	Underground SAC control centers, weapon and fuel depots.	ICBM missile sites (1960 - 1963).
3. Hard Site	100		ICBM missile sites (1963 - 1970).

* According to a synopsis entitled "A Test-Ban Primer" (Time, April 11, 1960), the Atlas ICBM is designed to carry a 3- or 4-MT weapon, while the USSR ICBM's are estimated to carry up to 8-MT in each nose cone. Warheads presently designed for Polaris and Minuteman solid fuel missiles are only about 1/2-MT, but this yield will likely be significantly increased in the future.

In order to determine for any given confidence levels the number of weapons required to knock out the targets in each category, the following three quantities must first be specified:

1) Peak overpressure as a function of distance from ground zero (depends on weapon size)
2) Weapon accuracy
3) Desired confidence level of destruction

Figure 2.2 gives the peak overpressure as a function of distance from ground zero for a 5-MT surface burst. As seen from the figure, the 100 psi overpressure level occurs at a distance of about a mile from ground zero, the 25 psi ring is about two miles, while 6 psi occurs a little beyond the four-mile radius.

Weapon accuracy is customarily defined in terms of the radius, r_o, of a circle within which half of the bombs would be expected to fall assuming a circular normal density distribution function for the scattering of the individual bombs about the intended ground zero location. The circular normal density distribution is described by the well-known relation:

$$g(r) = \frac{r}{\sigma^2} e^{-r^2/2\sigma^2} \tag{2.1}$$

where $g(r)$ = the probability that a bomb drops a distance "r" from the intended ground zero

σ = the standard deviation

and r = the distance from the intended ground zero.

Now, the probability, $p(r)$, that a bomb will drop <u>within</u> a distance r of the desired aiming point is given by:

$$p(r) = \int_0^r g(r)dr = \int_0^r \frac{r}{\sigma^2} e^{-r^2/2\sigma^2} dr = \frac{1}{2\sigma^2} \int_0^r e^{-r^2/2\sigma^2} d(r^2)$$

or,

$$p(r) = 1 - e^{-r^2/2\sigma^2} \tag{2.2}$$

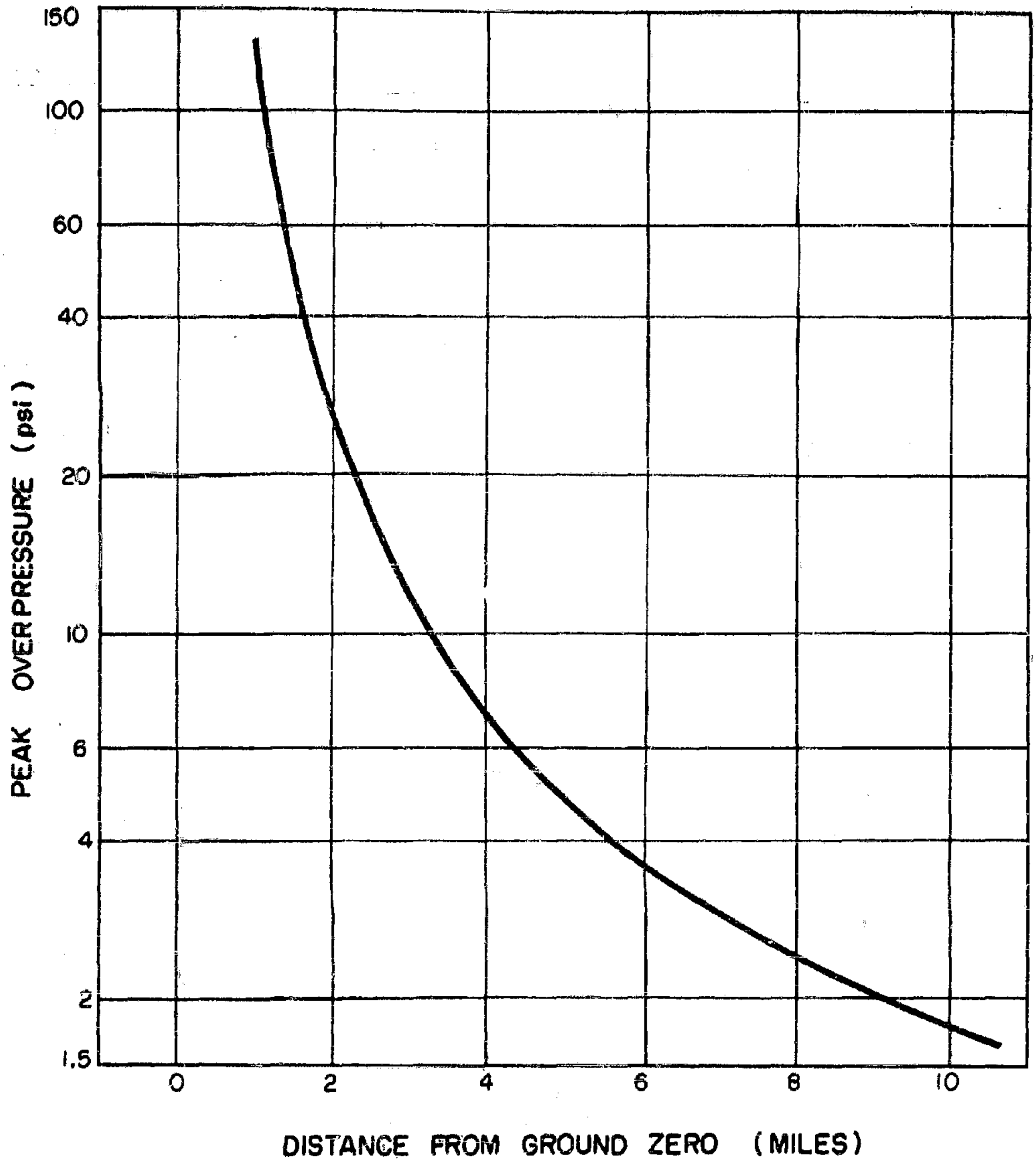


Fig. 2.2 Peak Overpressure Vs. Distance From Ground Zero For 5-MT Surface Burst (Ref. Fig. 3.94a in "Effects of Nuclear Weapons")

The radius, r_o, within which half of the bombs are expected to fall is the value of r for which p(r) = 1/2, or substituting in equation (2.2):

$$1/2 = 1 - e^{-r_o^2/2\sigma^2}$$

$$-\frac{1}{2}\left(\frac{r_o}{\sigma}\right)^2 = \ln\frac{1}{2}$$

from which,

$$r_o = 1.177\sigma \qquad (2.3)$$

"r_o" is defined as the circular probable error (abbreviated C.E.P.), and is seen to be just 17.7% larger than the standard deviation σ. Substituting r_o from equation (2.3) into (2.2), we have

$$p(r) = 1 - e^{-.692\left(\frac{r}{r_o}\right)^2} \qquad (2.4)$$

Thus, using Figure 2.2 and equation (2.4), we can calculate the probability, p(r), that a single 5-MT weapon will knock out a target in either of the three categories outlined in Table 2.4 as a function of the assumed weapon C.E.P. Table 2.4 lists these probabilities for four values of C.E.P. ranging from 1/2 to 2 miles.

TABLE 2.5

PROBABILITY OF DESTROYING HARDENED MILITARY TARGETS WITH SINGLE 5-MT WEAPONS OF DIFFERENT ACCURACIES

Peak Overpressure (psi)	Distance from GZ (miles)	Probability of Landing Within Distance			
		0.5 mi. CEP	1.0 mi. CEP	1.5 mi. CEP	2.0 mi. CEP
6	4.32	≈1	≈1	0.997	0.962
25	2.04	≈1	0.944	0.722	0.513
100	1.12	0.969	0.580	0.322	0.195

For example, under "soft site" conditions, where a peak overpressure of 6 psi is adequate to cause complete destruction or damage beyond economical repair to any parked aircraft* a 5-MT surface burst with a 2-mile C.E.P. has a probability of 0.962 of achieving this pressure level at the base. In other words, one such surface burst should render the site incapable of retaliation with a confidence of 0.962.

If we let P be the confidence level for destruction of any given target, then the number of weapons, n, that must be dropped to achieve this level of confidence is given by the relation:

$$P = 1 - (1 - p)^n \tag{2.5}$$

where p = probability that one weapon will knock out the target (i.e., land within the specified overpressure ring).

Substituting $(1 - p) = e^{-0.692(r/r_o)^2}$ from equation (2.4), and solving (2.5) for n, we have

$$-0.692n\left(\frac{r}{r_o}\right)^2 = \ell n(1 - P)$$

or,

$$n = 1.445\left(\frac{r_o}{r}\right)^2 \ell n \frac{1}{1 - P} \tag{2.6}$$

Figure 2.3 is a plot of equation (2.6) showing the number of 5-MT weapons required as a function of site hardness for C.E.P.'s from 0.5 to 2.0 miles and confidence levels of 90%, 95% and 99%. For example, to be 95% sure of knocking out a 100 psi target with a 1.5 mile C.E.P. weapon, eight weapons must be assigned to the target. On the other hand, only a single 5-MT weapon with a one mile C.E.P. need be assigned to a 25 psi target, or one with a 0.5 mile C.E.P. assigned to a 100 psi target for the same confidence level of destruction. Although the graph shows the number of weapons as a continuous variable, in practice only integral values of "n" are allowable for each target. These corresponding integral values of "n" for the three hardness categories, four different C.E.P.'s, and three confidence levels considered are listed in Table 2.6.

* See "Effects of Nuclear Weapons", pg. 173-176 and 237-239.

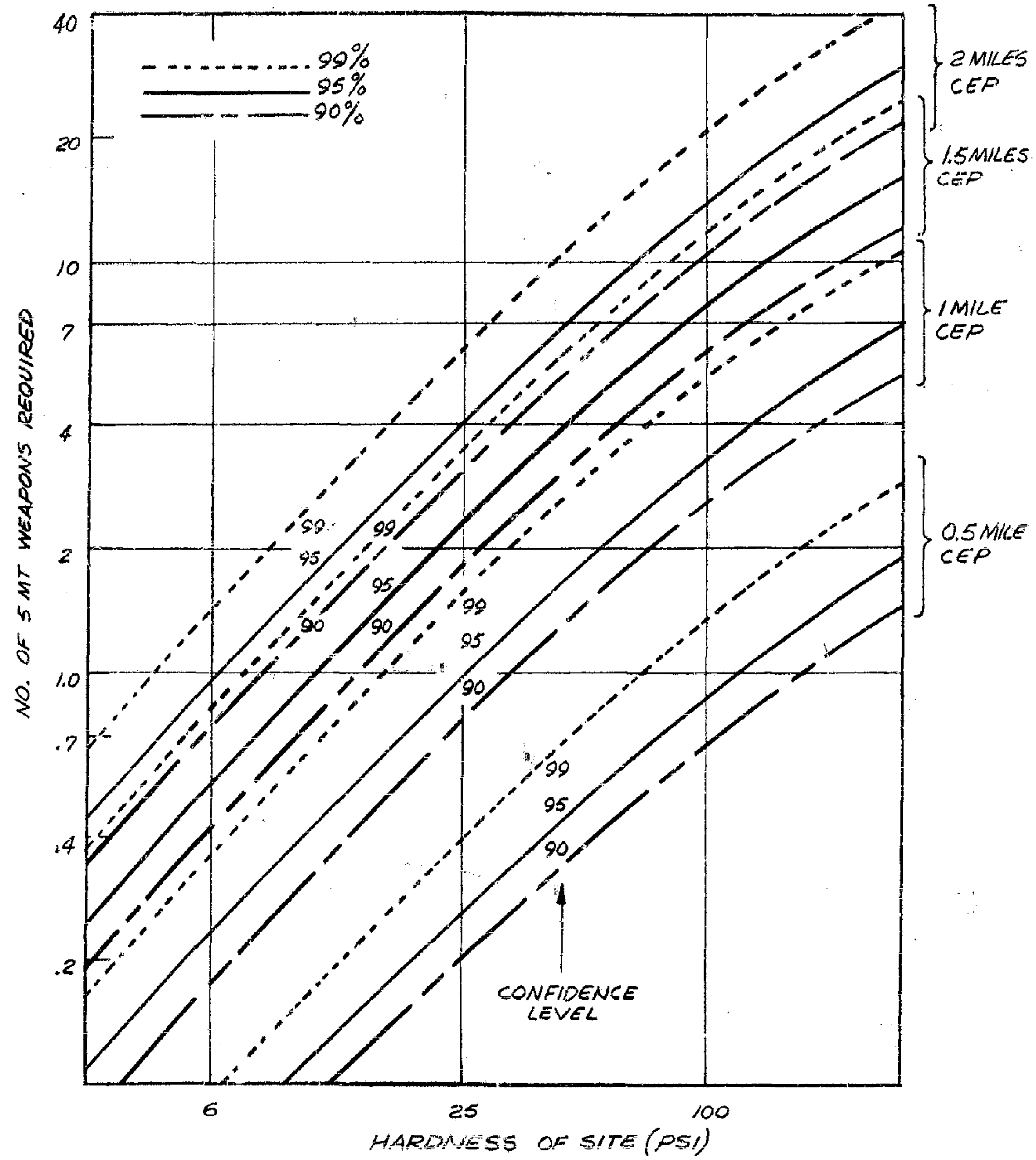


Fig. 2.3 No. of 5-MT Weapons Required Vs. Hardness of Site (For Different CEP's and Confidence Levels)

TABLE 2.6

NUMBER OF 5-MT WEAPONS WITH DIFFERENT
ACCURACIES REQUIRED FOR A GIVEN PROBABILITY
OF DESTROYING HARDENED MILITARY SITES

SITE Category	Peak Overpressure (psi)	NO. OF 5-MT WEAPONS REQUIRED												
		CEP →	0.5 MILES			1.0 MILE			1.5 MILES			2.0 MILES		
		Confidence Level →	90%	95%	99%	90%	95%	99%	90%	95%	99%	90%	95%	99%
Soft Site	6		1	1	1	1	1	1	1	1	1	1	1	2
Medium Hard Site	25		1	1	1	1	1	2	2	3	4	4	5	7
Hard Site	100		1	1	2	3	4	6	6	8	12	11	14	22

The only delivery systems capable of 1/2 mile C.E.P. accuracy or better at the present time are manned bombers; however, even if our air defense capability were not adequate to cope successfully with the bomber threat, the enemy would lose a tremendous advantage in surprise if he chose to use this method of delivery. Consequently, we have not considered the use of manned aircraft against the prime military targets. Bombers appear to have a far more effective role when employed against industrial and population centers <u>after</u> our prime retaliatory and air defense capability has been knocked out.

As for the accuracy of ICBM's, according to President Eisenhower's State of the Union message (Time, Jan. 18, 1960), "The Atlas ICBM has already had 15 successful test shots in a row at 5000-mile range, impacting at average, within two miles from target." And according to an announcement from Moscow (Time, Feb. 1, 1960), a missile fired from Siberia "Travelled about 7800 miles and landed less than 1-1/4 miles from the precalculated target point". These statements imply that the C.E.P. of present day ICBM's on both sides is in the range from one to two miles, and while these reports may give a somewhat over-optimistic impression of either our own or the enemy's over-all expected operational ICBM capability in 1960, they are believed to provide a good indication of our capability (and that of the enemy) perhaps two to three years hence. As for numbers of ICBM's, "By mid-1963, according to revised plans and estimates," (Time, Feb. 8, 1960), "the U. S. count will be 200-250, while the U.S.S.R.'s will be 400-500."

The above statements regarding the number and accuracy of long range missiles together with the Military Target List developed in the previous section (see Table 2.3) and weapon requirements listed in Table 2.6 above, indicate that a full scale attack on our retaliatory and air defense bases is likely to be well within the enemy's projected capability by mid-1963 based on a 95% confidence level for target destruction. We have, therefore, assumed for the purpose of analyzing the probable fallout threat over the continental U. S., that the enemy's attack on the 150 military targets listed in Table 2.3 consists of 5-MT missiles with 1.5 mile C.E.P, and that he desires to achieve at least a 95% confidence level of target destruction. This means that on the average not more than one base in 20 would be "spared", and is felt to be as high a confidence level as the enemy could expect to

achieve in light of all the other uncertainties. As for actual weapon requirements for the different targets, they are (from Table 2.6) as follows:

1) One 5-MT weapon on each soft (6 psi) site
2) Three 5-MT weapons on each medium hard (25 psi) site

and 3) Eight 5-MT weapons (for a total of 40-MT) on each of the 100 psi hard missile sites planned for the mid-1960's.

Applying this weapon criteria to the Military Targets listed in Table 2.3 results in a total of about 370 weapons dropped on these military bases throughout the country. Table 2.7 summarizes the number of military targets in the different hardness categories and total weaponage assigned (in megatons) for each of the eight OCDM regions.

TABLE 2.7

SUMMARY OF MILITARY TARGETS AND WEAPONAGE ASSIGNED

									Totals	
Priorities	1	2	3	4	5	6	7	8	Targets	Weaponage in Metagons
A_0	1	-	-	-	3	8	3	4	19	760
A_1	6	2	9	6	8	2	3	2	38	570
A_2	8	5	4	5	1	3	6	4	36	180
A_3	-	3	8	-	6	-	4	-	21	105
N_1	2	1	-	-	-	-	-	-	3	15
N_2	4	1	4	-	-	-	5	1	15	75
N_3	4	5	5	3	3	3	2	2	27	135
Total Targets	25	17	30	14	21	16	23	13	159	
Total Weaponage in Megatons	220	105	240	130	290	380	250	225		1840

The possible need (and weapons requirements) for cratering runways was also investigated, but a preliminary analysis indicated that the marginal benefit to the enemy in meeting this criteria would not justify the large increase in number of weapons and degree of accuracy required. As an example, it turns out that for a cratering confidence level of only 0.80, sixteen 5-MT weapons with 1/2 mile C.E.P. would be required. If planes could hope to land and pick up fuel and weapons, then this large expenditure in weapons to prevent use of the runways might have some justification, but we have assumed that 25 psi will knock out these supplies, so the value of the runway is only as a place to land and there will probably always be plenty of landing strips that could be used in the emergency.

Of the 19 missile base sites 17 are presently used by the Strategic Air Command for bomber bases. These are presumed to be hardened to about 25 psi and hence would require 3 weapons for destruction at the present time. The two purely missile sites, Vandenberg and Lowry, might at present be destroyed with single 5-MT weapons.

During the next 5 years the various missile sites will be organized, hardened and armed. At different periods in their lives, differing numbers of weapons will be required for destruction because of the dispersion of silos, the degree of centralized control, the hardness of silos and the accuracy of attacking weapons.

The seven Atlas D and Titan I bases, Cheyenne (semi-hard), Omaha (soft), Denver, Marysville, Mountain Home, Moses Lake and Rapid City, will all have centrallized radio-inertial guidance and therefore could be disabled by as few as eight weapons of 1-1/2 mile C.E.P., if the locations of the control centers were known accurately. These will probably become operational in the 1961-1963 period.

The ten Atlas E and Titan II bases, Spokane, Topeka, Salina, Lincoln, Roswell, Abilene, Altus, Plattsburgh, Tucson and Wichita, will all be hardened to at least 100 psi overpressure, have 9 to 12 widely dispersed missiles, and be individually controlled with all-inertial guidance systems. When these become operational, in the 1963-1965 period, it is quite possible that enemy missiles (as well as our own) will be improved so that one mile or even one-half mile C.E.P. accuracy will be characteristic. In the latter event, eight weapons could destroy most of retaliatory capability.

Hence, the uniform allotment of eight 5-MT weapons per missile site has been assumed as an average weaponage even though it is high for most sites for an attack in 1961 and low for many sites for an attack in 1965.

The dispersion, centralized control hardening and arming at Lompoc (Vandenberg AFB) will vary widely during the next five years depending upon the weapons being tested, the crews being trained and the development of the base.

The full weapon complement of 150 Minuteman at Malmstrom AFB in Great Falls, Montana will not be operational before 1965. At that time more than 100 weapons, even of one-half mile C.E.P. accuracy, would be required to destroy this large retaliatory capability.

All but one of the above noted 19 missile bases are west of the Mississippi River and 14 are far enough away from any major industrial and population centers so as not to present a serious blast or fallout hazard. The remaining five sites are, however, sufficiently close upwind of major industrial areas to be particularly serious hazards. These major industrial and population centers are as follows:

1) Denver, Colo.: Lowry AFB (18 Titan I missiles by mid-1961) is five miles east of the center of the city. Both blast and fallout would be very serious at all times of the year.

2) Los Angeles, Cal.: Vandenberg AFB (6 Atlas missiles now and up to 100 missiles of various types by 1965) is about 130 miles northwest of the city. Fallout would likely be very serious in winter, but under average wind conditions would tend to fall north of the city in the spring and fall. In summer, the average wind would carry the fallout considerably northwest of city, reducing the expected hazard still further.

3) Kansas City, Mo.: Forbes AFB (9 Atlas E missiles by 1962-1963) is 60 miles west, and Schilling AFB (which will have 12 Atlas E by 1962-1963) is 150 miles west of the city. Fallout on the city is likely to be greatest in winter. In spring and fall the wind velocity is generally lower so that the hazard from weapons dropped on Schilling AFB would be considerably reduced. In the summer, the average wind velocity is very much lower and the direction changes so that the heaviest fallout is most likely to fall northwest of Kansas City.

4) Fort Worth and Dallas, Tex.: Dyess AFB (12 Atlas E missiles by 1962-1963) is 140 and 170 miles respectively west of these cities. Fallout on these cities would likely be serious in winter and spring, but would tend on the average to fall southwest of these cities in the fall, and would have a very low probability of being a hazard in the summer.

2.2 INDUSTRIAL, GOVERNMENTAL AND POWER RESOURCE TARGETS

2.2.1 Priority Categories

The major factors considered in selecting the points of vulnerability in our economy and government are:

1) Immediate contribution to offensive retaliatory capability and air defense
2) Resources for repairing damage to retaliatory capacity
3) Civilian morale
4) Communication and control centers
5) Transportation hubs
6) National and state government centers

After reviewing the various available statistics such as population, population density, capital cities, amount of commercial activity, and amount of industrial activity, it was decided to base the priority of industrial targets on "value added by manufacturing", defined as follows by the Bureau of Census: "This measure is derived in the 1950 census by subtracting the cost of materials, supplies, and containers, fuel, purchased electric energy, and contract work from the value of shipments of manufacturing establishments. It avoids, therefore, the duplication in the value of shipments figure which results from the use of products of some establishments as material by others. It is considered to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas."* Figures are given for total value as well as by 20 different product categories.

* County and City Data Book, 1956, United States Government Printing Office, Washington, D. C., p. xxiii.

In general, these values reflect the over-all importance in terms of military manufacturing, transportation, communications, population and food distribution. They do not, however, reflect the centers of state government control since only 15 state capitals are in important manufacturing or commercial cities. Fifteen other state capitals are located in small metropolitan areas and have been included in the target list since the combinations of state governments with some manufacturing activity are of importance.

"Standard metropolitan areas" have been used to designate target locations. They are defined as follows by the Bureau of the Census: "Except in New England, a standard metropolitan area is a county or group of contiguous counties which contain at least one central city of 50,000 inhabitants or more. In addition to the county, or counties, containing such a city, or cities, contiguous counties are included in a standard metropolitan area if, according to certain criteria, they are essentially metropolitan in character and sufficiently integrated with the central city. The following criteria were used in determining the boundaries of standard metropolitan areas:

1) Each standard metropolitan area must include at least one city of 50,000 inhabitants or more. Areas may cross state lines.

2) Where two cities of 50,000 inhabitants or more are within 20 miles of each other, they will ordinarily be included in the same area.

3) Each county included in a standard metropolitan area must have either 10,000 non-agricultural workers or ten per cent of the non-agricultural workers in the area, or at least one-half of the county's population must have resided in minor civil divisions with a population density of 150 or more per square mile and be contiguous to the actual city.

4) Each county included in a standard metropolitan area must be economically and socially integrated with the central counties of the area. A county has been regarded as integrated if:

a) 15% or more of the workers living in the county work in the central county of the area, or
b) 25% or more of those working in the county live in the central county of the area, or

c) telephone calls from the county to the central county of the area average four or more calls per subscriber per month.* "

Value added is related to population but not to area or the presence of state capitals as follows: The 17 largest standard metropolitan areas alone contain:

1) 46% of the value added by manufacture
2) 31% of the population
3) 1% of the area
4) 4% of the state capitals.

(All figures refer to only the 48 states of continental United States.)

Four priority categories have been established on the basis of the most recent census data available (1950) in accordance with the following criteria:

1) First priority: 17 metropolitan areas with greater than $1,000,000,000 value added by manufacture <u>or</u> greater than 1,000,000 population.

2) Second priority: 27 metropolitan areas with greater than $300,000,000 value added by manufacture and greater than 300,000 population.

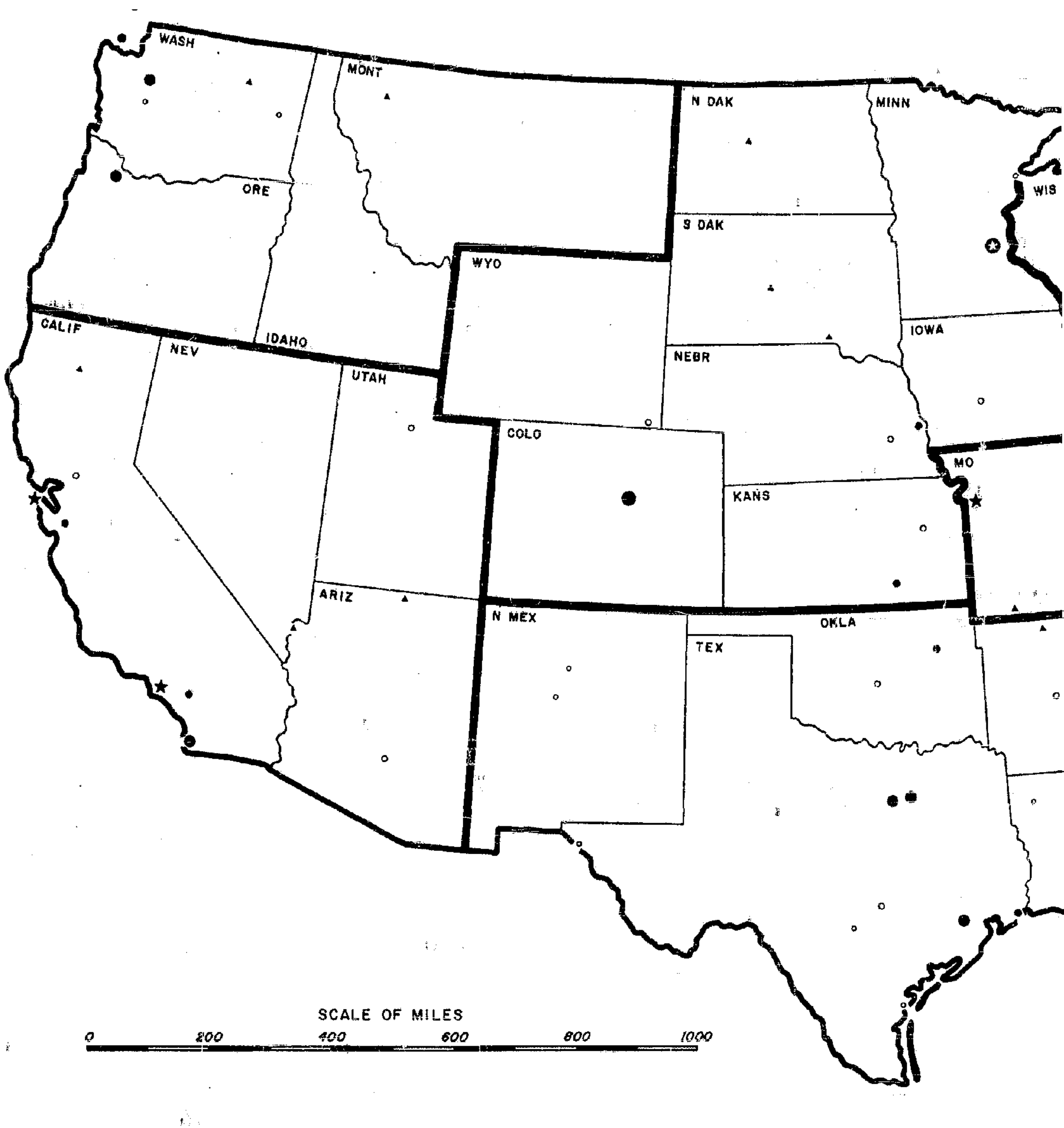
3) Third priority: 43 metropolitan areas with greater than $200,000,000 value added by manufacture and greater than 125,000 population.

4) Fourth priority: 37 metropolitan areas or cities with greater than $140,000,000 value added by manufacture, are state capitals with greater than $60,000,000 value added by manufacture, are centers for the manufacture of important military products with greater than $50,000,000 value added by manufacture, or are important centers for the manufacture of nuclear weapons.

Figure 2.4 shows the location of all of these targets with their priority and functional designations.

Table 2.8 lists all of the industrial and governmental targets along with appropriate statistics. Following it are footnotes explaining details of the Table. Immediately after the footnotes is a general explanation of the rationale for establishing the priority separation values and a comparison with other lists of targets.

* County and City Data Book, 1956, United States Government Printing Office, Washington, D. C., p. xi.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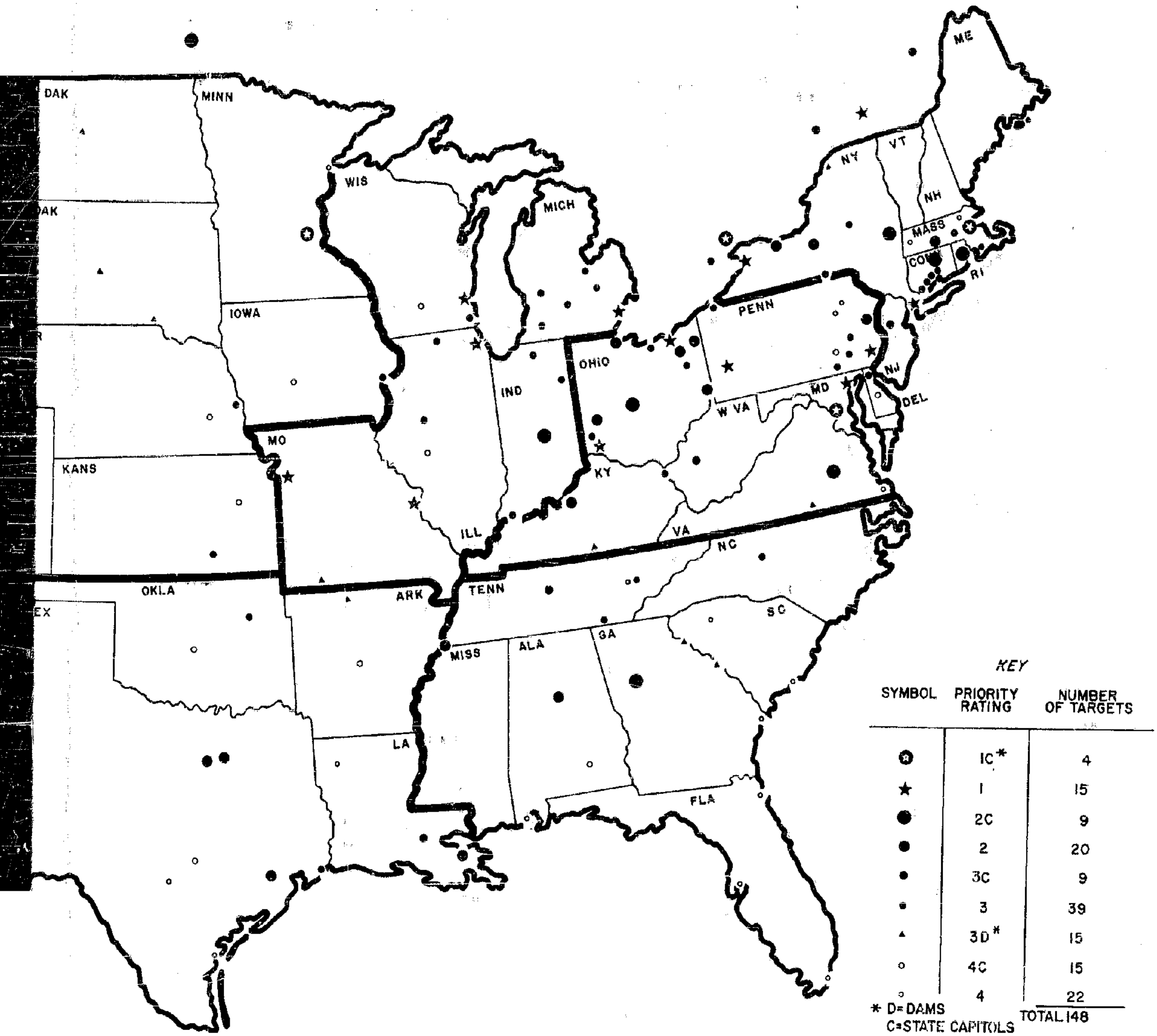

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Fig. 2.4 Location of Industrial, Governmental and Power Resource Targets in the United States and Southern Canada

TABLE 2.8

UNITED STATES AND SOUTHERN CANADIAN INDUSTRIAL AND GOVERNMENTAL TARGETS

(Arranged by OCDM Regions and States)

The table, which follows, lists all the non-military targets considered in this study. For each target area the following statistics are given:

1) Value added by manufacturing

2) Population

3) Area in square miles.

In addition, the assigned priority of the target and the assumed weaponage dropped are listed. When a military target exists within non-military target areas, its priority is also designated.

TABLE 2.8

UNITED STATES AND SOUTHERN CANADIAN INDUSTRIAL AND GOVERNMENTAL TARGETS

(Arranged by OCDM Regions and States)

State	Standard Metropolitan Area*	Value added by Manufacturing ($1,000,000's)	Population (1000's)	Industrial or Governmental Priority**	Military Priority (if applicable)	Area in Square Miles	Weaponage*** (in Megatons) In Addition To Military Attack
			OCDM REGION 1				
Conn.	Bridgeport	510	258	3	–	108	5
	Hartford	530	358	2C	–	346	5
	New Britain, Bristol	273	147	3	–	133	5
	New Haven	299	265	3	–	154	5
	Stanford, Norwalk	243	196	3	–	133	5
	Waterbury	308	155	3	–	182	5
Maine	—	-	-	-	—	-	-
Mass.	Boston	1972	2370	1C	$A_2N_2N_3$	770	20 +
	Lowell, Lawrence	198	260	4	—	192	5
	New Bedford, Fall River	242	274	3	—	255	5
	Pittsfield	140	67	4	—	111	5
	Springfield, Holyoke	502	407	2	A_1	333	5
	Worcester	348	276	3	—	286	5
N. H.	—	-	-	-	—	-	-
N. J. (see also N.Y.) (see also Pa.)	Trenton	303	230	3C	—	228	5
N. Y.	Binghamton	482	185	3	—	710	5
	Buffalo	1678	1089	1	A_2	1587	50
	New York, NE N.J. (incl. Jersey City), Newark	13,116	12,912	1	A_2N_2	3939	120 +
	Rochester	920	488	2	—	673	15
	Schenectady, Albany, Troy	585	514	2C	—	1405	30
	Syracuse	479	342	2	A_2	792	10 +
	Utica, Rome	328	284	3	A_1	2669	10 ++
R. I.	Providence	744	737	2C	N_2	494	5 +
Vt.	—	-	-	-	—	-	-
Region Total	21						325

* State capitals and other cities of less than 50,000 population are not parts of Standard Metropolitan Areas.
** State capitals are shown as C following priority.
*** See Section 2.2.2 for development of weapon criteria.
\+ See Note 1 at end of Table.
++ See Note 2 at end of Table.

(Cont'd)

TABLE 2.8 (Cont'd)

UNITED STATES AND SOUTHERN CANADIAN INDUSTRIAL

AND GOVERNMENTAL TARGETS

(Arranged by OCDM Regions and States)

State	Standard Metropolitan Area*	Value added by Manufacturing ($1,000,000's)	Population (1,000's)	Industrial or Governmental Priority**	Military Priority (if applicable)	Area in Square Miles	Weaponage*** (in Megatons) In Addition To Military Attack
			OCDM REGION 2				
Del.	Dover	na	6*	4C	A_2	na	- +
	Wilmington	387	268	3	—	787	10
D. C.	Washington	223	1464	1F. C.	A_2A_3	1488	40 +
Ky. (see also W. Va.)	Louisville	845	577	2	—	908	20
Maryland	Baltimore	1547	1337	1	—	1106	35
Ohio (see also W. Va.)	Akron	619	410	2	N_3	413	5 +
	Canton	449	283	3	—	573	5
	Cleveland	2101	1466	1	—	688	25
	Cincinnati	1319	904	1	—	730	25
	Columbus	661	503	2C	A_1N_3	538	10
	Dayton	747	457	2	A_1	881	5 +
	Hamilton Middletown	310	147	3	—	471	5
	Lorain Elyria	282	148	3	—	495	5
	Toledo	535	396	2	—	343	5
	Youngstown	874	528	2	A_2	1720	20 ++
Pa.	Allentown Bethlehem Easton	593	438	2	—	1082	20
	Erie	286	219	3	—	812	10
	Harrisburg	188	292	4C	A_3	1075	5
	Lancaster	289	235	3	—	945	10
	Philadelphia Camden, N. J.	4024	3671	1	N_3N_3	3550	110 +
	Pittsburgh	2481	2213	1	—	3053	100
	Reading	294	256	3	—	864	10
	Scranton	165	257	4	—	454	5
	Wilkes-Barre Hazelton	156	392	4	—	891	5
	York	349	203	3	—	914	10
Virginia	Norfolk Portsmouth	114	446	4	$A_3N_1N_2$	667	5
	Richmond	343	328	2C	—	734	15
W. Va.	Charleston	288	322	3C	—	1567	15
	Huntington Ashland, Ky.	210	246	3	—	1407	15
	Wheeling Steubenville, O.	404	354	2	—	1530	20 ++
Region Total	30						570

(Cont'd)

TABLE 2.8 (Cont'd)

UNITED STATES AND SOUTHERN CANADIAN INDUSTRIAL

AND GOVERNMENTAL TARGETS

(Arranged by OCDM Regions and States)

State	Standard Metropolitan Area*	Value added by Manufacturing ($1,000,000's)	Population (1,000's)	Industrial or Governmental Priority**	Military Priority (if applicable)	Area in Square Miles	Weaponage*** (in Megatons) In Addition To Military Attack
			OCDM REGION 3				
Alabama	Birmingham	482	569	2	—	1118	20
	Mobile	123	231	4	A_3	1248	5
	Montgomery	33	139	4C	A_2	790	- +
Florida	Jacksonville	124	304	4	N_2N_2	770	5
	Miami	141	495	4	A_1	2054	5
	Tampa / St. Petersburg	140	409	4	A_1	1304	5 + ++
Georgia	Atlanta	552	672	2C	N_3	1138	25
	Savannah	153	151	4	A_1	441	- +
Mississippi	—	-	-	-	—	-	-
N. Carolina	Winston-Salem	304	146	3	—	424	5
S. Carolina	Charleston	54	165	4	A_2	945	5
	Greenville	127	168	4	A_2	789	- +
Tenn.	Chattanooga	277	246	3	—	1024	10
	Knoxville	230	337	3	—	1428	10 ++
	Memphis	336	482	2	N_3	751	10 +
	Nashville	204	322	3C	—	533	5
	Oak Ridge	na	30*	4	—	na	5
Region Total	16						115
			OCDM REGION 4				
Illinois (see also Iowa)	Chicago	7893	6495	1	A_2N_3	3617	110 +
	Peoria	362	251	3	—	1277	15
	Rockford	313	152	3	—	520	5
	Springfield	111	131	4C	—	880	5
Indiana	Evansville	238	160	3	—	241	5
	Ft. Wayne	282	184	3	—	671	5
	Indianapolis	845	552	2C	—	402	10
	South Bend	320	205	3	—	467	5
Michigan	Detroit (Windsor, Can.)	4713	3016	1	A_1N_3	1965	55 +
	Flint	714	271	3	—	644	5
	Grand Rapids	454	288	3	—	862	10
	Kalamazoo	221	127	3	—	567	5
	Lansing	318	173	3C	—	559	5
	Saginaw	237	154	3	—	812	10
Missouri	Kansas City	1040	814	1	A_1A_2	1643	35 + ++
	St. Louis	2053	1681	1	N_3	2520	75 +
Wisconsin (see also Minn.)	Madison	96	169	4C	A_2	1197	5
	Milwaukee	1440	871	1	—	239	10
	Racine / Kenosha	315	185	3	—	610	5
Region Total	19						330

(Cont'd)

TABLE 2.8 (Cont'd)

UNITED STATES AND SOUTHERN CANADIAN INDUSTRIAL AND GOVERNMENTAL TARGETS

(Arranged by OCDM Regions and States)

State	Standard Metropolitan Area*	Value added by Manufacturing ($1,000,000's)	Population (1,000's)	Industrial or Governmental Priority**	Military Priority (if applicable)	Area in Square Miles	Weaponage*** (in Megatons) In Addition To Military Attack
			OCDM REGION 5				
Arkansas	Little Rock / N. Little Rock	68	197	4C	A_1	781	5
Louisiana	Baton Rouge	255	158	3C	—	462	5
	New Orleans	375	685	2	N_3	1118	15 +
	Shreveport	65	217	4	A_1	1732	5
New Mexico	Albuquerque	86	146	4	A_3	1163	5
	Los Alamos	na	10*	4	—	na	5
Oklahoma	Oklahoma City	106	325	4C	A_3	709	5
	Tulsa	203	252	3	—	572	5
Texas	Austin	18	161	4C	A_1	1015	- +
	Beaumont / Pt. Arthur	223	195	3	—	945	10
	Corpus Christi	72	165	4	N_3	398	5
	Dallas	508	615	2	N_3	893	20
	El Paso	51	195	4	A_1	1054	- +
	Ft. Worth	368	361	2	A_1	877	15 +
	Houston	869	807	2	—	1730	35
	San Antonio	111	500	4	A_3	1247	- +
Region Total	16						135
			OCDM REGION 6				
Colorado	Denver	314	564	2C	A_0	2918	40 ++
Iowa	Davenport / Rock Is., Ill. / Moline, Ill.	282	234	3	—	873	10
	Des Moines	186	226	4C	—	594	5
Kansas	Topeka	57	105	4C	A_0	546	- +
	Wichita	333	222	3	A_0	999	- +
Minnesota	Duluth / Superior, Wis.	79	253	4	A_2	7591	5
	Minneapolis	1081	1117	1C	N_3	1721	55 +
Nebraska	Lincoln	64	120	4C	A_0	845	- +
	Omaha	214	366	3	A_0	1533	5 +
N. Dakota	—	—	-	-	—	-	-
S. Dakota	—	—	-	-	—	-	-
Wyoming	Cheyenne	6	32*	4C	A_0	7	- +
Region Total	10						120

(Cont'd)

TABLE 2.8 (Cont'd)

UNITED STATES AND SOUTHERN CANADIAN INDUSTRIAL

AND GOVERNMENTAL TARGETS

(Arranged by OCDM Regions and States)

State	Standard Metropolitan Area*	Value added by Manufacturing ($1, 000, 000's)	Population (1, 000's)	Industrial or Governmental Priority**	Military Priority (if applicable)	Area in Square Miles	Weaponage*** (in Megatons) In Addition To Military Attack
			OCDM REGION 7				
Arizona	Phoenix	115	332	4C	A_2	9226	- +
California	Los Angeles Long Beach	5042	4370	1	N_3	4853	155 +
	Sacramento	112	277	4C	A_2A_3	985	5
	San Bernardino Riverside Ontario	205	452	3	A_1A_2	27, 310	15 ++
	San Diego	390	557	2	N_2N_2	4258	20 + ++
	San Jose	264	291	3	N_2	1305	15
	San Francisco Oakland	1674	2241	1	$A_1A_2N_2N_2N_3$	3314	110
Nevada	—	-	-	-	—	-	-
Utah	Salt Lake City	161	275	4C	—	764	5
Region Total	8						325
			OCDM REGION 8 (excl. Alaska and Hawaii)				
Idaho	—	-	-	-	—	-	-
Montana	—	-	-	-	—	-	-
Oregon	Portland	475	705	2	A_2	3663	35 + ++
Washington	Seattle	521	733	2	$A_2N_3N_3$	2134	45
	Spokane	136	222	4	A_0	1763	- +
	Tacoma	146	276	4	A_1	1676	- +
Region Total	4						80

(Cont'd)

TABLE 2.8 (Cont'd)

UNITED STATES AND SOUTHERN CANADIAN INDUSTRIAL

AND GOVERNMENTAL TARGETS

(Arranged by OCDM Regions and States)

Province	City	City Population (1000's)	Greater Area Population (1000's)	Priority	Weaponage*** (in Megatons)
		SOUTHERN CANADA (excl. Maritime Provinces)			
		1956 Census			
Alberta	Edmonton	226	na	3C	5
British Col.	Vancouver	366	665	2	15
	Victoria	55	na	3C	5
Manitoba	Winnipeg	255	409	2C	15
Ontario	Hamilton	240	na	3	5
	Ottawa	222	na	3F. C.	5
	Toronto	668	1358	1C	30
Quebec	Montreal	1109	1621	1	30
	Quebec City	171	na	3C	5
Canadian Total	9				115

Notes: Windsor, Ontario is adjacent to Detroit (No. 1 Priority)
Niagara, Ontario is adjacent to Buffalo (No. 1 Priority)

Notes to Table 2.8

1. Weaponage values marked + are less than the amounts based on area and value criteria because missiles dropped on the adjacent military targets would effectively destroy a significant part of the surrounding industrial capacity.

2. Weaponage criteria are shown in detail in Section 2.2.2, below. Weaponage values marked ++ do not follow the standard criteria because the political and census boundaries (and other considerations) would yield values out of line with those devised for the rest of the 124 U.S. target areas. Exceptions are explained in Section 2.2.2.

3. "na" denotes data not available.

4. Military priorities are shown for those Military Targets that are either within 20 miles of the center of the principal city listed or within 10 miles of the urban areas as illustrated in the Hammond Atlas.*

*Hammond's Library World Atlas, 1958, C. S. Hammond and Co., Maplewood, N. J.

There are three cities with greater than one billion dollars value added by manufacturing but less than one million population (Milwaukee, Cincinnati and Kansas City), and one city with greater than one million population but less than one billion dollars value added by manufacturing (Washington). These four cities have been assigned first priority because of their great importance. They seem quite clearly to be more important than Rochester, N. Y., and Houston, Texas, the most important manufacturing and population centers with second priority.

The separation between second and third priority is less distinct. The round numbered borderlines tend to place in second priority multi-industry areas, a relatively large number of state capitals and areas that often are adjacent to important military bases. Richmond, Va., Memphis, Tenn., and Denver, Colo., have 314 to 343 million dollars value added by manufacturing; 328,000 to 564,000 population; and two are state capitals. They are on the low end of the second priority list and seem to be more important than Flint, Mich., and Bridgeport, Conn., the most important areas in the third priority group. These latter have values added of 714 and 510 million dollars but populations of 271,000 and 258,000 respectively. They are among the 28 areas that meet one but not both criteria and are, therefore, in the third or lower priority groups.

The lower limit of third priority was established to include almost all of the remaining important concentrated industrial areas. Nashville, Tenn., and Tulsa, Okla., just meet the lower limit of value added by manufacturing but are well above the minimum population. Winston-Salem, No. Carolina, and Kalamazoo, Mich., just meet the lower limit of population but are well above the minimum value added by manufacturing. Of the 28 that met only one of the two criteria for second priority, 18 are in third. They include all remaining areas with greater than 300 million dollars value added by manufacturing (since all such areas exceed 125,000 population).

The separation between third and fourth priorities is not of great importance since the weaponage (described in Section 2.2.2 below) is almost the same (even though arrived at by different criteria).

The separation of areas by priority is illustrated and rationalized quite clearly in Pennsylvania. Of its ten targets

2 are in first priority: Philadelphia and Pittsburgh

1 is in second priority: the Allentown-Bethlehem-Easton area

4 are in third priority: York, Reading, Lancaster and Erie

3 are in fourth priority: Harrisburg, Scranton and Wilkes-Barre

Two of the target areas in third priority, above, and one in fourth priority, below, are combinations of pairs of small area, dense-population standard metropolitan areas. They and their neighboring areas form continuous targets so that it seems reasonable to call them single targets even though, by Census Bureau definition, they are separate. The special pairs are: New Bedford-Fall River (Massachusetts) and Racine-Kenosha (Wisconsin) in third priority, and Lowell-Lawrence (Massachusetts) in fourth.

The fourth priority group contains 37 areas (or cities with less than 50,000 population) with the following variety of criteria:

1) Nine with greater than $140,000,000 value added by manufacture. The areas are concentrated and the products are of prime industrial importance. (Three are also state capitals.)

2) Five state capitals with greater than $60,000,000 value added by manufacture.

3) Eight cities with greater than $50,000,000 value added by manufacture. These are cities with products of major military significance, and in addition, each city is only six to 15 miles away from one of the military targets listed in Section 2.1.

4) Two cities of special nuclear weapon significance (Los Alamos and Oak Ridge).

5) Thirteen cities that meet the specifications of paragraphs 1, 2 and 3 above but are so close (less than six miles) to adjacent military bases that the weapons assigned to military targets would very likely destroy the manufacturing facilities as well. These cities have been listed with the notation + (See note 1 to Table 2.8).

The above criteria leave certain sizeable cities off the target list. Among them are Battle Creek (Michigan), Portland (Maine), Augusta (Georgia), Galveston (Texas), and Stockton (California). It is recognized that the dividing line is arbitrary and could, if desirable, be changed. (Note: Battle Creek is adjacent to Fort Custer, A_2 priority on the Military Target list.)

On the basis of the above criteria all but 18 of the 48 state capitals have been included as targets. These 18 are centers of duly constituted governmental authority but represent targets of such limited size and industrial importance that they have been omitted from this list. They are:

Annapolis, Maryland	Boise, Idaho
Augusta, Maine	Carson City, Nevada
Bismarck, North Dakota	Columbia, South Carolina
Concord, New Hampshire	Olympia, Washington
Frankfurt, Kentucky	Pierre, South Dakota
Helena, Montana	Raleigh, North Carolina
Jackson, Mississippi	Salem, Oregon
Jefferson City, Missouri	Santa Fe, New Mexico
Montpelier, Vermont	Tallahassee, Florida

A few large Canadian cities have been added to the above 124 American industrial and governmental targets. They were selected on the basis of population and proximity to the United States such that weapons dropped on them might produce fallout on some part of the United States. Priority assignments were made on the basis of population to match approximately the importance of comparable U. S. areas.

All of the above criteria and data are based on 1950 statistics. Some of the areas, notably in California, Florida and Texas, have grown in industrial importance and population far more rapidly than have areas in other parts of the country. The locations of military bases reflect this growth and the concentrations of military targets tend to assign weaponage to those areas that are probably under-emphasized by the statistics sighted above. To a small extent, also, the criteria were drawn so as to include rather than exclude the most important industrial areas in these and other rapidly growing parts of the country. It is expected that the 1960 Census will produce some figures significantly larger than those used. It is not anticipated, however, that the over-all Fallout Threat would differ significantly if a restudy were to be made when the 1960 Census Data will be available.

TARGET DAMS

Electrical power, water supply and irrigation facilities differ greatly in different parts of the country. In the heavily-industrialized sections, and particularly in the northeast and north central cities, electrical power is generated in steam plants. These are usually within the city limits and are, therefore, a part of the industrial target complex. Water supply tends to be well dispersed and is also a part of the already stated target complex.

In the south, central and western states, however, a relatively small number of dams supply a relatively large percentage of the electrical power, and a large percentage of the water supply used for irrigation. Fifteen important dams have been selected which meet the following criteria:

1) Power output greater than 200,000 kilowatts (and as large as 2,000,000 kilowatts).

2) Water storage greater than 915,000 million gallons (and as large as 10,000,000 million gallons).

3) All of the dams which meet the above criteria also are greater than 1200 feet long and 200 feet high.

While these dams represent only a relatively small fraction of the total power resources of the United States, they are very important resources in their respective large areas of the country.

Table 2.9 shows the locations, names and statistics of these dams.

These dams have been considered third priority targets due to their relatively lower vulnerability to attacks of the weapon accuracy expected. Dams are assumed to present only slightly larger targets than runways of retaliatory air bases. On this basis a given number of weapons would produce much more damage when dropped on the larger targets that first and second priority metropolitan areas present. However, since the areas dependent upon these dams for power and irrigation are large and the construction time and cost are great, they are considered to be of higher priority than the fourth priority areas listed above.

The next two largest dams meet the water storage minimum but not the power minimum. They are Fort Peck, Montana, and Kentucky Reservoir, and are not included as targets.

Table 2.10 summarizes the number of industrial, government and dam targets in each priority. Breakdowns are given by OCDM regions and by the presence of adjacent military targets.

TABLE 2.9

UNITED STATES TARGET DAMS

(Arranged by OCDM Regions and States)

OCDM Region	State(s)	Name	Power Generated (1000's kw)	Water Reservoir Capacity (billion gallons)	Weaponage*** (megatons)
1	New York-Canada	St. Lawrence Seaway	n. a.	n. a.	5
2	Kentucky	Wolf Creek-Lake Cumberland	270	1984	5
	Virginia - N. Carolina	John H. Kerr	204	915	5
3	Georgia - S. Carolina	Clark Hill	280	945	5
	Georgia - S. Carolina	Hartwell	330	931	5
4	Missouri	Table Rock	200	1128	5
5	Arkansas-Missouri	Bull Shoals	320	1762	5
6	N. Dakota	Garrison	400	7495	5
	S. Dakota	Fort Randall	320	2053	5
	S. Dakota	Oahe	595	7691	5
7	Arizona-Utah	Glen Canyon	prob. > 200	9137	5
	Arizona-Nevada	Hoover-Lake Mead	1354	9719	5
	California	Shasta	379	1466	5
8	Montana	Hungry Horse	285	1130	5
	Washington	Grand Coulee-F. D. R.	1974	3064	5
Total Dams	15				75

Note: All have been assigned Number 3 priority.

*** See Section 2.2.2 for weapon criteria.

TABLE 2.10

SUMMARY OF INDUSTRIAL, GOVERNMENTAL AND DAM TARGETS

(from Tables 2.8 and 2.9)

OCDM REGIONS

Priorities		1	2	3	4	5	6	7	8	Can.	Total	Criteria
1	Adj. to Mil.	3	2	-	4	-	1	2	-	-	12	>$1, 000, 000, 000 Mfg. or
	All Targets	3	6	-	5	-	1	2	-	2	19	>1, 000, 000 Pop.
2	Adj. to Mil.	3	4	2	-	3	1	1	2	-	16	>$300, 000, 000 Mfg. and
	All Targets	6	9	3	1	4	1	1	2	2	29	>300, 000 Pop.
3	Adj. to Mil.	1	-	-	-	-	2	2	-	-	5	>$200, 000, 000 Mfg. and
	All Targets	11	12	6	12	4	6	5	2	5	63	>125, 000 Pop.
												Dams >200, 000 kw and >915, 000, 000, 000 gallons
4	Adj. to Mil.	-	3	8	1	8	4	2	2	-	28	Miscellaneous
	All Targets	2	5	9	2	9	5	3	2	-	37	Special manufacture
												State Capitals
												Mfg. adj. to military
Totals	Adj. to Mil.	7	9	10	5	11	8	7	4	-	61	
	All Targets	22	32	18	20	17	13	11	6	9	148	
Weaponage (Megatons) In Addition to Military Attack	All Targets	330	580	125	385	140	135	340	90	115	2240 MT	

An effective attack on the continental United States would certainly include all 111 of the 0, 1 and 2 priority military bases and would, in the process, partially destroy the 45 metropolitan areas adjacent to some of them.

An all-out attack on the United States and Southern Canada might call for a total of 4080 megatons, 1840-MT for all the military bases in Section 2.1 and 2240-MT as summarized above. It is believed that the enemy will have this many weapons (about 800, 5-MT bombs), and the means to deliver them within the next five years.

2.2.2 Weapon Criteria

A 5-MT surface burst will cause serious damage* to brick industrial-type buildings out to a radius of seven miles. This degree of damage to such a 150-square-mile area is taken to be an appropriate objective in any industrial area which has greater than $500,000 per square mile of value added by manufacture. All of the first priority metropolitan areas, except Washington, have average industrial values exceeding that amount. It therefore seems reasonable to assign one weapon for every 150 square miles in first priority areas. On this basis the New York metropolitan area would be subjected to 130-MT, Los Angeles to 160-MT, Boston to 35-MT, and Buffalo to 55-MT (see Table 2.8 for complete tabulation).

The procedure adopted for the analysis was to place a 14-mile grid over each metropolitan area and locate weapons at each corner intersection (after providing for specific weapons on military targets within the boundaries of the metropolitan area). Little is known of the effects at fringe distances due to multiple weapon blasts. This level of attack, however, is expected to cause heavy damage to all but a few fringe region reinforced concrete multi-story, massively constructed buildings and leave the 17 first priority areas with almost no capacity for industrial operation or reconstruction.

Most of the second priority metropolitan areas have greater than an average of $300,000 per square mile of value added by manufacture and the important industry tends to be concentrated in the city centers. It was determined that the great majority of the industrial activity would be severely damaged if 5-MT weapons were assigned on the basis of one for every 250 square miles of the standard metropolitan area. For fallout analysis purposes some weapons were located on the centers of each of the major constituent cities while in other areas an 18-mile grid was used. Five of the second priority areas include large tracts

* At seven miles from ground zero multi-story wall bearing buildings (brick apartment house type, up to three stories) would have exterior walls badly cracked and interior partitions badly cracked or blown down (Class C damage). Multi-story reinforced-concrete buildings (with concrete walls, small window area, up to five stories) would have windows and doors blown in and interior partitions cracked (Class D damage). (See "Effects of Nuclear Weapons", 1957, Atomic Energy Commission, Washington, D.C., pg. 230, 249.)

of undeveloped land. In these instances, the weaponage assigned was reduced as tabulated below. Large undeveloped tracts within these five standard metropolitan areas may be noted by comparing the standard metropolitan area maps in the City and County Data Book with a population distribution map.* This special situation arises because the Bureau of Census definition follows county lines rather than the edges of industrial zones or residential sections. The adjustment is a simple and reasonable one to make.

Most of the third priority metropolitan areas likewise have greater than an average of $300,000 per square mile of value added by manufacture, but extend for less than 750 square miles in area. With the same assumptions about industry concentration in the city centers, it appeared reasonable to direct single 5-MT weapons at such targets. Other industrial targets in the third priority group cover larger areas. All but three of these extend over less than 1600 square miles and have high enough concentration of manufacturing activity to suggest the assignment of one 5-MT weapon for every 500 square miles of area. Accordingly the two or three weapons per target are considered aimed for maximum industrial damage at the centers of the principal cities. Reduced weaponage for the less concentrated targets is tabulated below.

The power and water dams vary in length from 0.2 to 4 miles. A single 5-MT weapon with a 1-1/2 mile C.E.P. would destroy most of the 15 dams listed. Missile error may, however, leave one or two of the dams intact. It is possible that the very large power (1,400,000 kw) and water storage (10,000,000 million gallons) capacities of Hoover Dam combined with its relatively short length (1200 feet) make it a multi-weapon target (or require a weapon with greater accuracy). Similarly the locks of the Saint Lawrence Seaway might require additional weapons of 1-1/2 mile accuracy (or a more accurate weapon).

In general the fourth priority targets cover areas so small that one properly placed 5-MT weapon could cause almost complete destruction. Only in the Tampa-St. Petersburg region is the metropolitan area large and important enough to justify using two weapons to insure destruction of industrial capacity.

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* Population Distribution, Urban and Rural: 1950, Map No. 290739 U. S. Government Printing Office, Washington, D. C.

A tabulation of all weaponage departures from the above formulae is as follows:

Priority	Std. Metropolitan Area	Area (Sq. Mi.)	Weaponage (in MT) (inc. military)	Remarks
1	Kansas City, Mo.	1643	40	Area formula of 55-MT seems excessive in comparison with Milwaukee(10) and Cincinnati(25).
2	Denver, Colo.	2918	80)	Large undeveloped areas within the boundaries are not likely targets. Also very high priority military targets are within the standard metropolitan area limits.
2	San Diego, Cal.	4258	30)	
2	Portland, Ore.	3663	40	Large undeveloped areas.
2	Youngstown, Ohio	1720	25	" " "
2	Wheeling, W. Va.) Steubenville, Ohio)	1530	20	" " "
3	San Bernardino, Cal) Riverside, Cal.) Ontario, Cal.)	27,310	35	Very large undeveloped area in this, the largest area county in the country.
3	Utica, N.Y.) Rome, N.Y.)	2669	25	Large undeveloped area.
3	Knoxville, Tenn.	1428	10	Large undeveloped areas.
4	Tampa, Fla.) St. Petersburg, Fla.)	1304	20	One 5-MT weapon for St. Petersburg in addition to 3 weapons on the Tampa SAC base.

The definitions and numbers of targets along with weapon criteria are shown for each priority category in Table 2.11 below.

TABLE 2.11

SUMMARY OF INDUSTRIAL TARGET AND WEAPON CRITERIA

Priority	Definition: Value Added by Mfg. (millions of dollars)		Definition: Population (thousands)	No. of Targets	Weapon Criteria	Weaponage (MT) (Excl. Military)
1	>1,000	or	>1,000	19	5MT per 150 mi^2	1190
2	> 300	and	> 300	29	5MT per 250 mi^2	510
3	> 200	and	> 125	48	5MT per 500 mi^2	345
3	dams: >200,000 kw and > 915 billion gal.			15	5MT each	75
4	Misc. mfg. values, state capitals, etc.			37	5MT each	120
		TOTALS		148		2240

2.2.3 Comparison of Targets and Weaponage with Other Studies

The 159 military targets combine with the 148 industrial, governmental, and dam targets to total 225 target complexes. These have been compared with the targets listed for Operation Sentinel II in October, 1957,* those listed by U. S. News and World Report on December 21, 1959,** and those listed by the Holifield Congressional Subcommittee on Radiation in the hearings on June 22 - 26, 1959.***

2.2.3.1 Comparison with Operation Sentinel II Targets

The report of Operation Sentinel II listed 146 targets of which 112 are common to the above list of 225. Most of the remaining 34 in the Sentinel report are military installations which were among the more important ones at that time, but have since that date been superseded in importance by the newer missile and Strategic Air Command bases. It is believed that the targets that appear in this report, but are not in the Sentinel report, constitute the most important military bases at this time and that no further consideration need be given to the omitted military locations. There are five state capitals listed for Operation Sentinel II that are among the 18 omitted in this report and noted above. These are considered somewhat less important than eight state capitals listed in Table 2.8, but not listed in the Operation Sentinel II target list. These eight are:

Albany, New York	Montgomery, Alabama
Baton Rouge, Louisiana	Nashville, Tennessee
Charleston, West Virginia	Richmond, Virginia
Dover, Delaware	Topeka, Kansas

* Operation Sentinel II, October 23-24, 1957, p. 6-21.

** U. S. News and World Report, December 21, 1959, p. 56-57, based on an article by H. Kahn of Stanford Research Institute.

*** "Biological and Environmental Effects of Nuclear War", Hearings before the Congressional Subcommittee on Radiation, June 22-26, 1959.

2.2.3.2 Comparison with Targets Listed in U. S. News and World Report

Summary of U. S. Industrial and Governmental Targets Listed in Table 2.8		Number of Targets Listed in U. S. News and World Report	Remarks
Priority	Number		
1	17	17	
2	27	26	Richmond, Va., omitted
3	43	2	These areas have low value added by manufacture relative to their large populations.
4	37	5	

Of the remaining four targets in U. S. News and World Report, two are operational missile sites (Cheyenne and Cape Canaveral), and two are relatively low priority industrial targets by the criteria of this report. These two, with their specifications are Wichita, Kansas, a third priority industrial but an A_0 missile base target; and Albuquerque, New Mexico, a fourth priority industrial and an A_3 military target.

The population criterion, rather than an industrial one, also underrates Peoria, Ill., and Grand Rapids, Mich. It places greater emphasis on the high population, lower industrial importance of Knoxville, Tenn., Wilkes-Barre, Pa., and San Antonio, Texas.

2.2.3.3 Comparison with Targets Listed in June 1959 Holifield Subcommittee Hearings*

The report of the Holifield Committee lists 224 targets in 189 target areas. Specific weaponage is also given so that a direct comparison can readily be made, both of the nature of the attack and the magnitude and location of lethal fallout for specified sets of wind conditions. Almost all of the more important military and industrial targets appear on both lists. In terms of severity, the Holified list has the following properties in comparison to the combined military and industrial attack of this report:

* Strike Output, Holifield Committee Project (PAF 214), (copy dated 15 January 1960).

84% as many targets areas

35% of total weaponage in megatons

32% as many weapons (average size 5-MT)*

An important difference between the two target lists is the much smaller weaponage assigned by the Holifield list to the large area first and second priority industrial centers. Twenty-five metropolitan areas listed in this report were assigned more than 20-MT. The weapon comparison between the two target lists for these areas is shown in Table 2.12.

The effect of the Holifield attack might be to destroy almost completely, the secondary and tertiary industrial (and military) centers, but leave the first priority centers with enough facilities to continue operation at more than 50% of capacity. It is also apparent that fallout from the far smaller concentration of weapons on major industrial centers would be significantly less intense in the hottest areas and that lethal outdoor areas would be much smaller. As outlined in Chapter 6, the areas most in need of high quality fallout shelter constitute only a small part of the area of the U. S. A., but the structures must protect a large part of the population. The Holifield list does not highlight quite so dramatically the most critical areas nor does it cover as many areas. These differences are, however, ones of degree rather than of kind.

A more detailed comparison between the attack of this report and that of the Holifield Committee report is shown in Appendix A at the end of this chapter.

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* Holifield report uses 10-, 8-, 5-, 3-, 2- and 1-MT weapons depending on the target importance. This report standardized on 5-MT weapons for analysis simplicity as described previously in this chapter.

TABLE 2.12

COMPARISON OF WEAPONAGE FOR HIGH PRIORITY, LARGE AREA TARGETS*

Metropolitan Area	Weaponage (in megatons) Assigned by this Report	Assigned by Holifield Report
Los Angeles - Long Beach	160	20
San Francisco - Oakland	145	48
New York - N.E. New Jersey	130	38
Philadelphia - Camden	120	20
Chicago	120	20
Pittsburgh	100	26
St. Louis	85	18
Denver	80	16
Detroit	75	20
Minneapolis - St. Paul	60	10
Seattle	60	18
Buffalo	55	10
Washington, D. C.	50	36
Portland	40	10
Kansas City	40	20
Boston	35	28
Baltimore	35	22
Houston	35	11
San Diego	30	8
Schenectady - Albany - Troy	30	8
Atlanta	30	10
Cleveland	25	18
Cincinnati	25	18
Youngstown	25	8
Dallas	25	10

* Weaponage for Military Targets within the Metropolitan areas has been included.

2.3 SPECIFIC ATTACK PATTERNS

Many different attack patterns may be postulated for assessing the fallout threat over the Continental United States. It has been assumed that a minimum attack would certainly include all high priority military targets. As outlined in Section 2.1, there are 75 military establishments with weapon carrying devices and weapons capable of reaching and destroying any potential enemy's military bases and industrial facilities. An all-out attack on the U. S. and Southern Canada would perhaps include most if not all of the 225 target complexes outlined in Sections 2.1 and 2.2. For the purpose of assessing the location of the regions of highest and lowest fallout and the identification of isointensity levels in between, two specific attack patterns have been outlined and will be analyzed in detail in Chapter 6. These are intended to be neither the heaviest nor the lightest that might occur in the event of a nuclear war in the 1960-65 period, but they do serve to delineate the fallout threat and can be examined for the important considerations of the local variations in this threat as a function of seasonal differences in wind direction and velocity. The lighter attack is directed only against military targets while the heavier one includes in addition to these military targets, the industrial, governmental and dam targets listed in Tables 2.8 and 2.9. The weaponage tabulated is only that actually landing on the Continental U. S. It is assumed that the enemy has a sufficient number of weapons and vehicles to destroy our overseas and allied bases, to provide for ineffective missiles, and still be able to deliver the attack described. No provision, however, has been made for large-scale delivery errors which would place weapon blasts and fallout in Continental U. S. areas not now considered attractive targets.

2.3.1 Military Attack

In all probability the enemy would concentrate his ICBM fire power, with its low warning time advantage and assumed 1.5 mile C.E.P. accuracy, on our 75 high priority missile and SAC sites, while the remainder of the 1840-MT military attack, directed against some 84 lower priority military targets as outlined in Section 2.1, could be delivered by either ICBM's or, if necessary, manned bombers. The emphasis in bomber attacks would be on the possibility of bombing alternate targets if the bomber crews were to find their prime targets already destroyed or no longer suitable targets for any of a variety of tactical or equipment reasons.

The fallout from an attack on all 159 important military bases was chosen to delineate the areas which would likely have serious fallout levels under average winter and summer wind conditions. These areas are shown in Chapter 6.

2.3.2 Combination Military and Industrial Attack (See Figure 2.5)

It might be theoretically possible to paralyze the industrial, governmental and power complex of the Continental United States and Southern Canada (the above 148 targets and the communication facilities connecting them) for a very long time by destroying a relatively small number of critical centers. Such an objective would require very high level intelligence to identify and locate all the several score such centers, and a very high order of weapon reliability and accuracy to reach and destroy them. It is believed that a potential aggressor has many more 5-MT weapons available than the few score required above but that it would not risk leaving the actual manufacturing facilities available to be run by those key men who would surely survive and who could reconstruct or replace the critical facilities. There is also some doubt that enemy intelligence and accuracy is high enough to warrant such a tactic.

An aggressor with an intelligence service of the highest order but without the missile accuracy required for an attack on critical centers with single weapons might well choose to replicate such an attack in an attempt to achieve paralysis of our economy with the least number of weapons.

It has been assumed that the enemy has enough more weapons and delivery systems at his disposal, after attacking our military facilities, to attempt to destroy our manufacturing facilities themselves rather than just the critical centers which manage and control these facilities. The 450 weapons when distributed among the 148 targets outlined above would destroy more than three quarters of our industrial capacity so that it would take many years for the survivors to rebuild the economy. Such an attack is or will soon be well within the capability of the enemy.

In actual practice, after determining the level of attack, the enemy would unquestionably select specific targets in each standard metropolitan area. The weapons would not be aimed in the regular grid patterns used in this study of radioactive fallout. The 14-mile spacing for weapons dropped on first priority targets and 18-mile spacing for large second priority targets was assumed for

simplicity in analysis. While the blast areas so created may be in some error it is believed that, to a first approximation, the distribution of fallout for the assumed wind conditions is substantially correct.

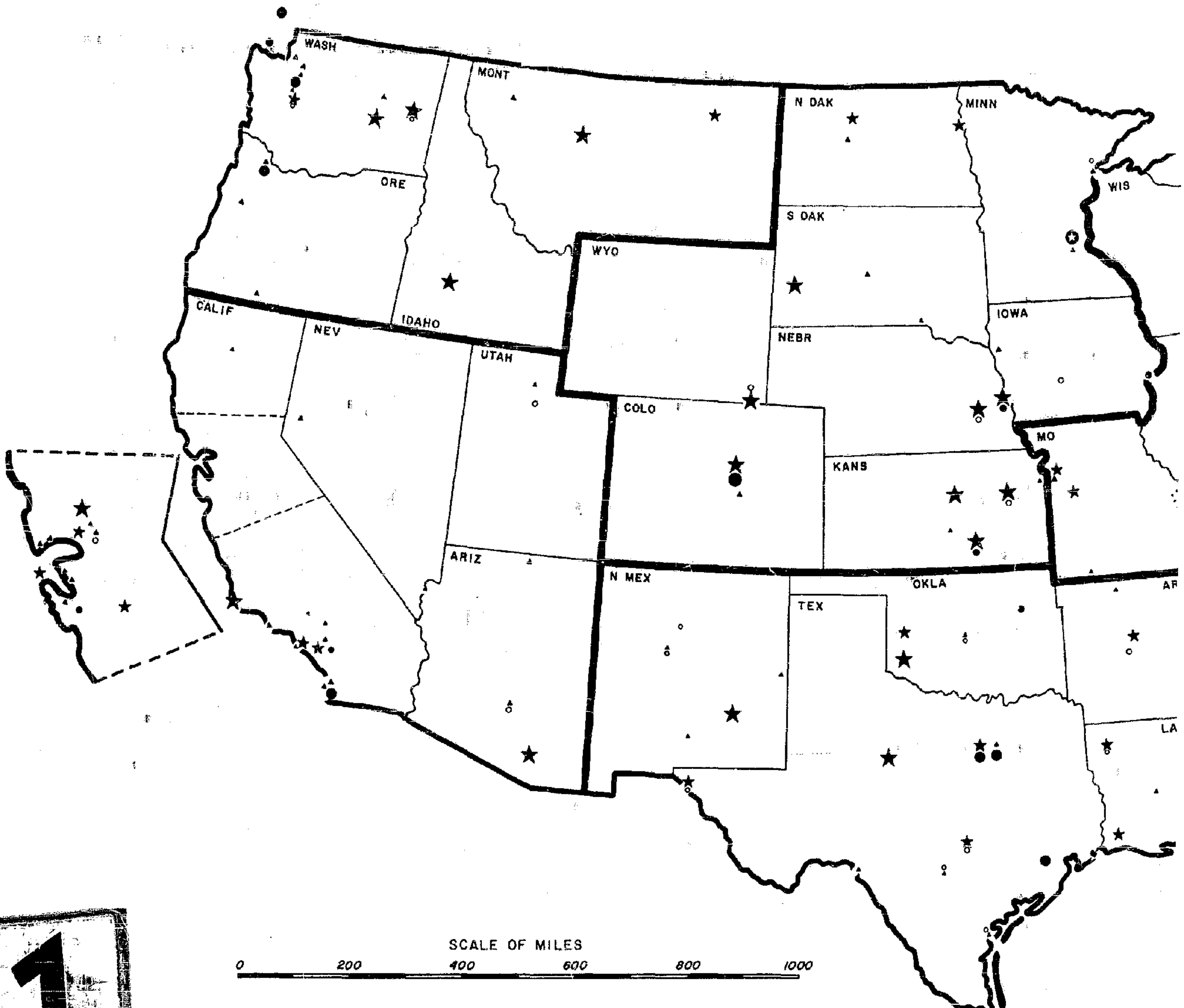
A more detailed analysis was made of the manufacturing facilities in five large standard metropolitan areas to corroboate both the weaponage and spacing assumptions. The data and observations are as follows:

Attack on the New York Standard Metropolitan Area

The New York-Northeastern New Jersey standard metropolitan area has manufacturing facilities producing more than $13,116,000,000 in value added by manufacture. The area covers about 4000 square miles so that the average value added is $3,300,000 per square mile. The greatest concentrations of manufacturing, more than $20,000,000 average added value per square mile, are in two boroughs of New York City (Brooklyn and Manhattan) and in ten cities and towns in the northeastern corner of New Jersey (Bayonne, Belleville Town, Hoboken, Jersey City, Newark, Passaic, Paterson, Perth Amboy, Union City and West New York Town). Concentrations of more than $5,000,000 per square mile exist in 16 other cities and concentrations of more than $1,000,000 per square mile exist in six other cities. All but one of these 34 manufacturing cities, towns and boroughs are within 30 miles of the center of New York City (see Figure 2.6), and altogether they cover less than 600 square miles so that they could be destroyed with, perhaps, a dozen weapons. The remaining 80% of the New York metropolitan area contains manufacturing facilities adding more than $3,200,000,000 in product value. This residual 3400 square miles has an average added value by manufacture of more than $900,000 per square mile and therefore may be considered a very worthwhile target area. It would take a total of 26 5-MT weapons to destroy all of the concentrated manufacturing capability and the two military targets within the New York standard metropolitan area.

Attack on the Los Angeles Standard Metropolitan Area

The Los Angeles-Long Beach standard metropolitan area is slightly larger than New York in size but has a little less than half the value added by manufacturing. The average value added is $1,000,000 per square mile. The total value added is $5,042,000,000 in an area of about 5000 square miles. Burbank is the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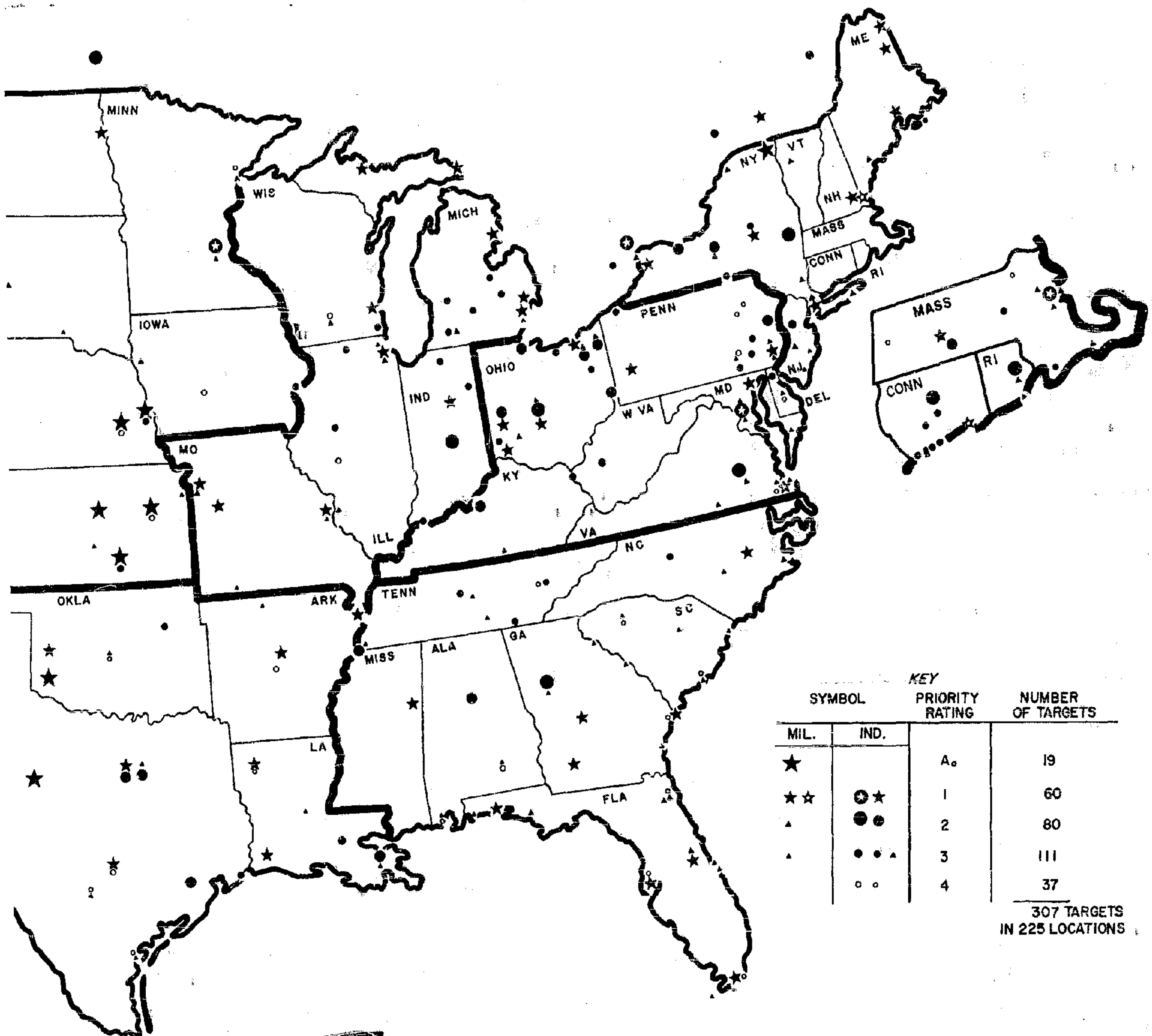
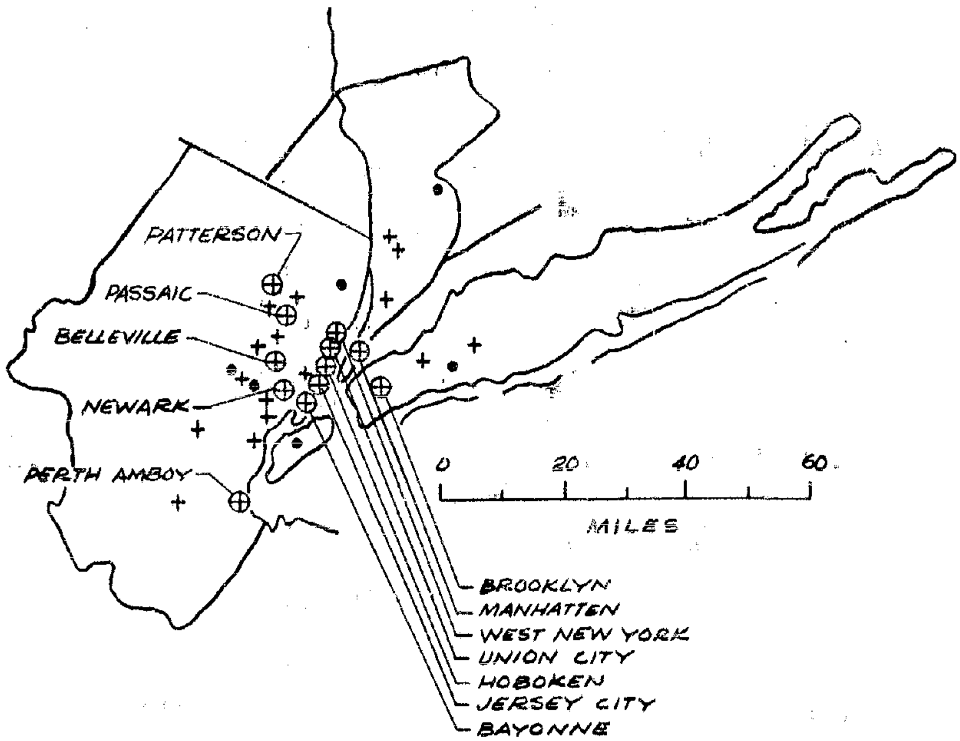


Fig. 2.5 Location of Military, Industrial, Governmental and Power Resource Targets (Combined Attack)



3939 Square Miles Area
$13, 116, 000, 000 Value Added By Manufacture
$3, 300, 000 Average Value Added Per Square Mile
Outside of the 34 cities, towns and boroughs
indicated, the average is $960, 000 per square mile

KEY

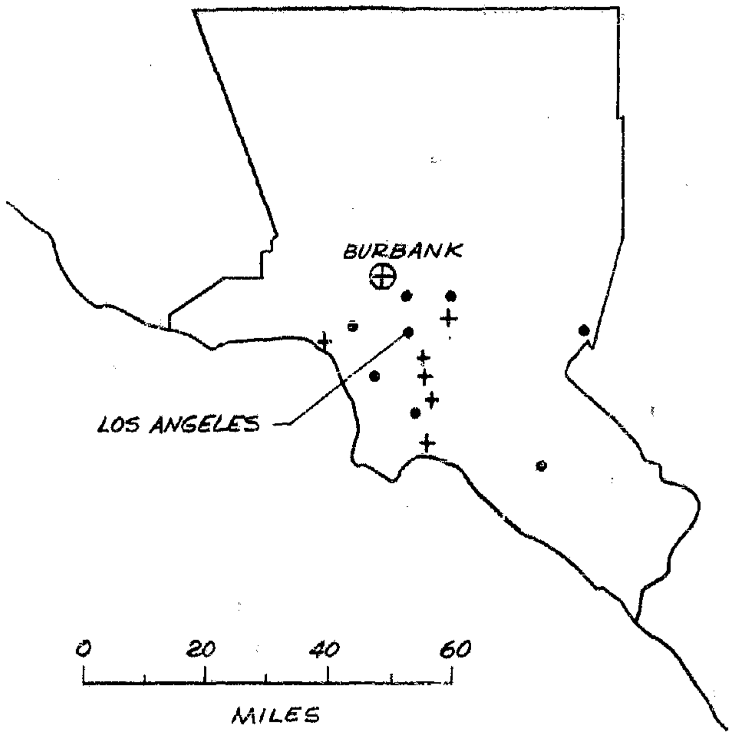
⊕ 12 (Cities,		with averages > $20, 000, 000 per sq. mi. value added by manufacture
+ 16	Towns,	with averages > $ 5, 000, 000 per sq. mi. value added by manufacture
• 6	Boroughs)	with averages > $ 1, 000, 000 per sq. mi. value added by manufacture
34		

Fig. 2.6 Major Cities in the New York - Northeastern New Jersey Standard Metropolitan Area

only city in the area with a concentration of greater than $20,000,000 average value added per square mile. Concentrations of more than $5,000,000 per square mile exist in six cities and concentrations of more than $1,000,000 per square mile exist in eight other cities. Most of these 15 manufacturing cities are within 30 miles of the center of Los Angeles (see Figure 2.7), and altogether cover approximately 600 square miles so that they could be destroyed with about ten weapons. The remaining 90% of the Los Angeles metropolitan area contains manufacturing facilities adding more than $1,800,000,000 in product value. Since this residual 4200 square miles contains many large establishments that manufacture missile and aircraft systems and has an average added value by manufacture of more than $400,000 per square mile an aggressor might try to destroy all except those few large undeveloped areas which he might identify by a detailed study of the area. The elimination of a few of the 32 weapons allocated to this area would reduce the blast area north of Los Angeles and, to a small extent, the areas of very high fallout which are north-east of Los Angeles. If, however, only half as many weapons (16 instead of 32) were dropped on Los Angeles, large amounts of manufacturing capability would remain intact and the serious fallout situation would be reduced significantly. But even at one quarter the assigned weaponage, Los Angeles, because of its lack of basements or other shelter, would have one of the most serious shelter problems in the country.

Attack on the Detroit Standard Metropolitan Area

The Detroit standard metropolitan area is half the size and has about one-third the value added by manufacture of New York. Its area is 2000 square miles. The total value added is $4,713,000,000 and the average value added is $2,400,000 per square mile. Dearborn, Hamtramck and Highland Park have concentrations greater than $20,000,000 average value added per square mile. Concentrations of more than $5,000,000 per square mile exist in three cities and one other city has a concentration of more than $1,000,000 per square mile. All of these seven manufacturing cities are within 20 miles of the center of Detroit (see Figure 2.8) and cover about 200 square miles so that they could be destroyed with as few as four weapons. The remaining 90% of the Detroit metropolitan area contains manufacturing facilities adding more than $1,200,000,000 in product value. Since this residual 1800 square miles has a high average concentration of $700,000 value added per



4853 Square Miles Area
$5, 042, 000, 000 Value Added by Manufacture
$1, 000, 000 Average Value Added Per Square Mile
Outside of the 15 cities indicated, the average
is $430, 000 per square mile

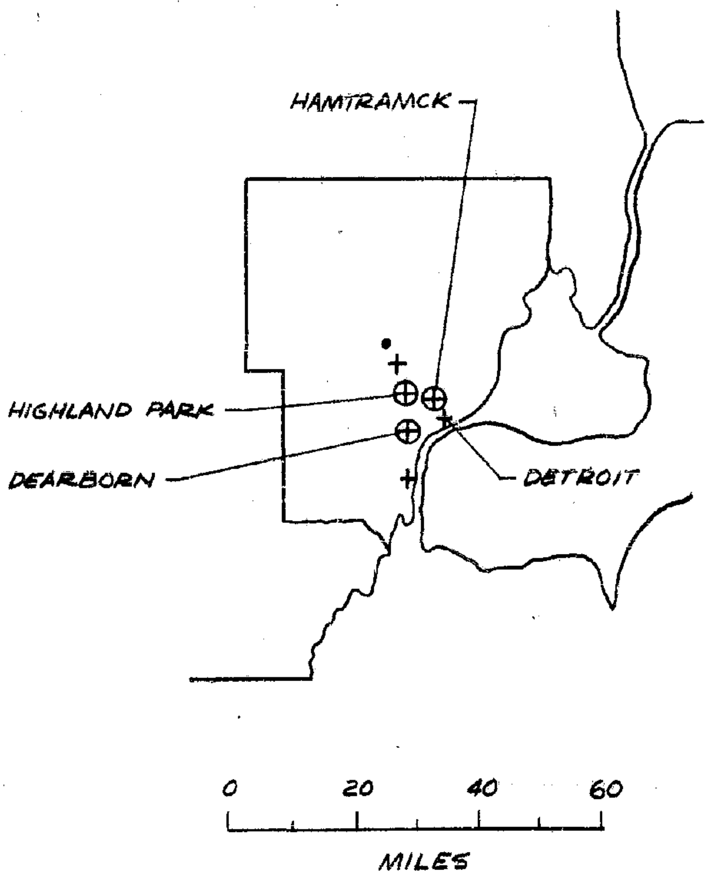
KEY

⊕ 1 City with averages > $20, 000, 000 per sq. mi. value added by manufacture

\+ 6 Cities with averages > $ 5, 000, 000 per sq. mi. value added by manufacture

• 8 Cities with averages > $ 1, 000, 000 per sq. mi. value added by manufacture
15

Fig. 2.7 Major Cities in the Los Angeles - Long Beach Standard Metropolitan Area



1965 Square Miles Area
$4, 713, 000, 000 Value Added By Manufacture
$2, 400, 000 Average Value Added Per Square Mile
Outside of the 7 cities indicated, the average
is $680, 000 per square mile

KEY

⊕ 3 Cities with averages > $20, 000, 000 per sq. mi. value added by manufacture

+ 3 Cities with averages > $ 5, 000, 000 per sq. mi. value added by manufacture

• $\frac{1}{7}$ City with averages > $ 1, 000, 000 per sq. mi. value added by manufacture

Fig. 2.8 Major Cities in the Detroit Standard Metropolitan Area

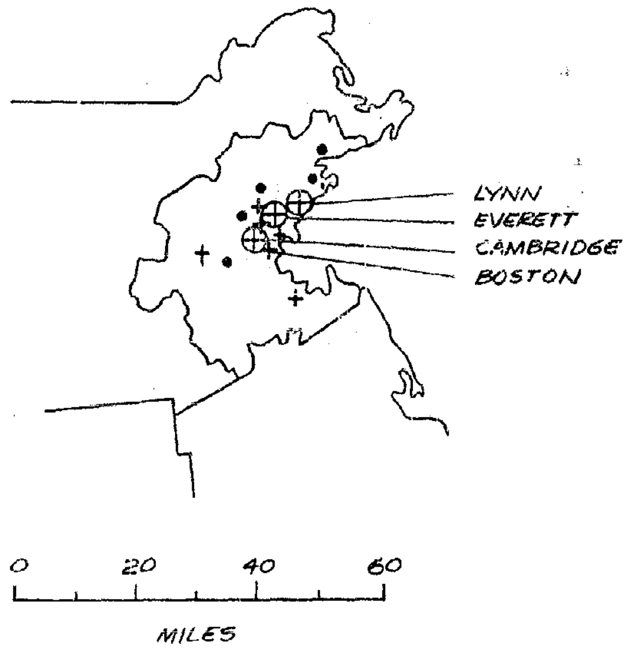
square mile and contains many heavy industrial machine and vehicle manufacturing companies, the enemy might well treat the area as a target to be completely destroyed. It would take a total of 15 5-MT weapons to destroy the two military targets (including one SAC base) and all of the above industrial capacity.

Attack on the Boston Standard Metropolitan Area

The Boston standard metropolitan area is approximately one half the size and has one half the value added by manufacture of Detroit. Its average value added of $2,600,000 per square mile is about the same as that of Detroit. The Boston metropolitan area covers 770 square miles (not including the contiguous metropolitan areas of Brockton, Lawrence, Lowell, Providence and Worcester). The total value added in the Boston area is approximately $2,000,000,000. Cambridge, Everett and Lynn have concentrations greater than $20,000,000 average value added per square mile. Concentrations of more than $5,000,000 per square mile exist in six cities, and in five other cities the concentration is greater than $1,000,000 per square mile. All of these 14 cities are within 20 miles of the center of Boston (see Figure 2.9) and cover less than 200 square miles so that four properly placed weapons could destroy them. The location of three military targets in the Boston area is such that the total of seven weapons (as well as the weapons on contiguous metropolitan areas) would also destroy the residual $400,000,000 manufacturing capacity in the 770 square miles of the Boston standard metropolitan area. (Average value added per square mile in the residual area is $660,000.)

Attack on the San Francisco Standard Metropolitan Area

The San Francisco-Oakland standard metropolitan area has the lowest industrial concentration of the five areas studied in detail. Its average value added by manufacture of $500,000 is occasioned by $1,674,000,000 total value added in an area of 3300 square miles. San Leandro is the only one of the cities in the area with a concentration of greater than $20,000,000 average value added per square mile. Concentrations of more than $5,000,000 per square mile exist in four cities and concentrations of more than $1,000,000 per square mile exist in three other cities. These eight cities are within 30 miles from the center of San Francisco (see Figure 2.10). They cover less than 200 square miles but are separated so that it would take at least five weapons just to destroy these centers. The seven weapons



770 Square Miles Area
$1, 972, 000, 000 Value Added By Manufacture
$2, 600, 000 Average Value Added Per Square Mile
Outside of the 14 cities indicated, the average
is $660, 000 per square mile

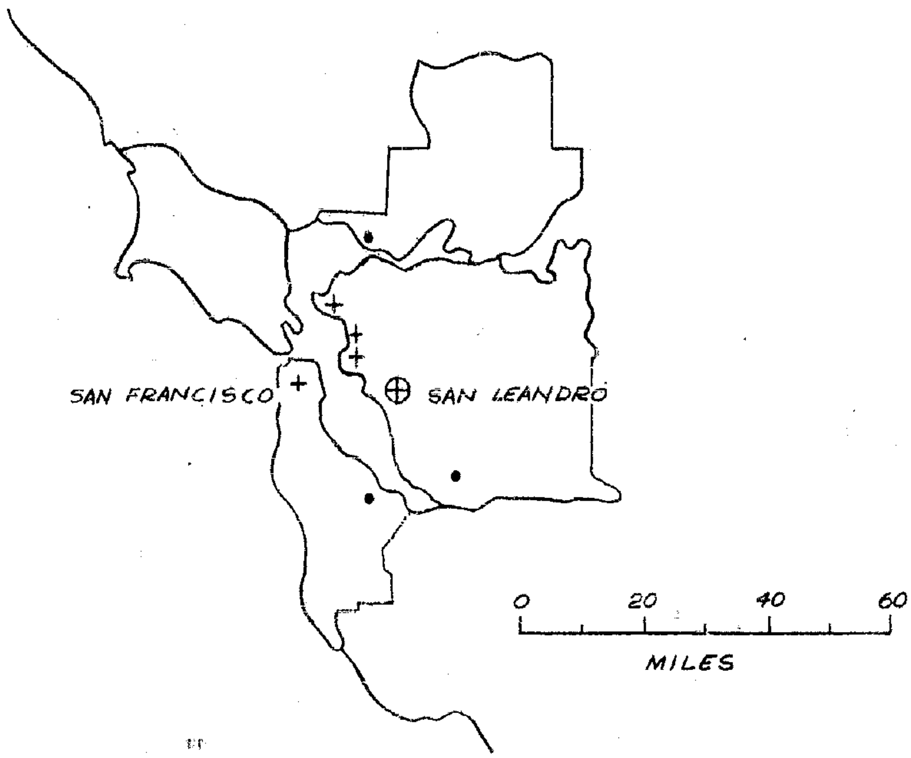
KEY

⊕ 3 Cities with average > $20, 000, 000 per sq. mi. value added by manufacture

+ 6 Cities with average > $ 5, 000, 000 per sq. mi. value added by manufacture

• 5 Cities with average > $ 1, 000, 000 per sq. mi. value added by manufacture
14

Fig. 2.9 - Major Cities in the Boston Standard Metropolitan Area



3314 Square Miles Area
$1, 674, 000, 000 Valued Added By Manufacture
$505, 000 Average Value Added Per Square Mile
Outside of the 8 cities indicated, the average
is $170, 000 per square mile

KEY

⊕ 1 City with average > $20, 000, 000 per sq. mi. value added by manufacture

+ 4 Cities with average > $ 5, 000, 000 per sq. mi. value added by manufacture

• 3/8 Cities with average > $ 1, 000, 000 per sq. mi. value added by manufacture

Fig. 2.10 Major Cities in the San Francisco - Oakland Standard Metropolitan Area

assigned to the five military targets in the San Francisco area combined with the above five would destroy more than half of the industrial capacity of the area. In this instance the area formula for assigning weapons to first-priority industrial targets results in the allocation of weapons to residual area with a concentration as low as $170,000 per square mile. The San Francisco area is, however, cut up by the large Bay so that weapons allocated to the variety of targets will inevitably dissipate some of their destructive force over water. A detailed study of the undeveloped areas might well show that fewer than 29 weapons could destroy the five military targets (7 weapons) and the manufacturing facilities in the 3300 square miles (22 weapons). If, for example, such an analysis were to show that eight more weapons (in addition to the seven on the military and the five in the major city targets) would destroy effectively all of the industrial facilities, the fallout shown on the map in Figure 6.7 would be reduced by approximately one-third. The lethal fallout is shown to cover large areas east and southeast of San Francisco. In the absence of readily available basement shelter* even half the estimated fallout would present a critical problem to residents of the San Joaquin valley.

The weaponage assigned to first priority industrial targets tends to dramatize the fallout problem for large suburban areas downwind of the major cities. Where basement shelter is available, in the Northeast and North Central states, large scale radiation casualties can be avoided. Where adequate fallout shelter is lacking for all or most of the population, in the West and South, the fallout would cause millions of casualties even if substantial reductions were made in weaponage.

A comparison of the weaponage assigned in this study with that tabulated by others (see Section 2.2.3) shows that the need for shelter is by and large independent of the differences in weaponage. Of all the major U. S. metropolitan areas, when allowance is made for the available shelter, St. Louis probably presents the greatest difference in expected radiation casualties due to the difference between

* See Report TO-B 60-30, pp 8: "only 15 to 20% of postwar homes in San Francisco have basements."

the 17 weapons (85-MT) used in this study as compared, for example, with the 18-MT assigned to the same area in the Holifield Committee Attack*. These casualties would occur in southern Illinois and Indiana.

2.3.3 Expected Casualties

An attack of the level of the Combination Military and Industrial Attack, described in Section 2.3.2, would cause casualties numbering in the millions. This section presents a rough estimate of the probable number of survivors assuming today's level of preparedness, and for varying degrees of additional shelter protection which may be forthcoming during the next five years.

On the basis of the 1950 Census and available data on population distribution, it is assumed that half the population of the Continental U. S. lives in the target areas of the combined attack referred to above. An additional quarter lives outside of the immediate target areas but well within the downwind heavy fallout areas. An estimate of the number of persons in different categories relative to blast, fallout, and shelter has been made and is shown in Table 2.13.

If we assume no preplanned shelter program, then all those in categories III, IV, V, and VI must be counted as casualties, bringing the national total to 83 million, or 55% of the population, based on the 1950 census. In a recent article in the Bulletin of the Atomic Scientists,** Ralph Lapp presents a summary of the casualty estimates from the 1446-MT attack prepared by the Joint Committee on Atomic Energy (JCAE) for the June, 1959, hearings of the Holifield Subcommittee on radiation. He also summarizes the casualty figures for two series of attacks analyzed by the Institute of Defense Analyses (IDA). In the first series, the prime objective is the retaliatory and defense potential of the country, while the objective in the second series is to kill as many people as possible. The attacks ranged from a few hundred to tens of thousands of megatons.

* "Biological and Environmental Effects of Nuclear War", Hearings Before the Congressional Subcommittee on Radiation, June 22-26, 1959.

** Lapp, Ralph E., "What is the Price of Nuclear War?", Bulletin of the Atomic Scientists, October 1959.

TABLE 2.13

ESTIMATE OF POPULATION IN DIFFERENT BLAST, FALLOUT AND SHELTER CATEGORIES

Category	Description of Area	No. of People	Per Cent	Cumulative Per Cent
I	Live outside heavy fallout area for any wind condition.	15,000,000	10	10
	Live outside heavy fallout area for the wind conditions at the time of the attack.	24,000,000	15	25
II	Live outside blast and thermal damage areas in the northern part of the U. S. but within heavy fallout areas. This group could survive by using the existing fallout shelter capability.	28,000,000	20	45
III	Live outside blast and thermal damage but within heavy fallout areas. This group could survive if only a minimum shelter program were instituted. The program would consist of fitting out existing facilities and training the population to get into and stay in shelters.	10,000,000	6	51
IV	Live outside blast and thermal areas in southern part of the U. S. but within heavy fallout areas where shelter is grossly inadequate. A minimum shelter construction program in key areas could provide fallout shelter for this group at a cost estimated at perhaps half a billion dollars.	6,000,000	4	55
V	Live within target areas. A major construction program for shelters incorporating some measure of blast protection in all target areas would provide shelter for this surviving group even though many of the shelters constructed were destroyed along with those individuals who managed to reach such shelter. This program is estimated to cost perhaps several billion dollars.	15,000,000	10	65
VI	Live within the expected severe blast and thermal damage areas. Some people in these areas would probably survive direct attack because they happened to be in deep basements, tunnels and other natural blast shelters. A program for providing adequate blast shelter to protect these people does not appear economically feasible at this time.	52,000,000	35	100

The above estimates are very rough approximations based on 1950 Census data. These numbers were derived from the data and assumptions shown in Table 2.14.

Figure 2.11 shows the per cent casualties as a function of the total megatonage for each series. Also shown plotted are the points representing the 1446-MT JCAE attack prepared for the Holifield committee, and the 4080-MT combined attack described earlier in this chapter. It is interesting to note that the casualties from each of these attacks fall about midway between the two curves, as would be expected since they both represent a combination of military and industrial targets.

The important point for Civil Defense, however, is not just to get agreement on how many will die if no shelter program is instituted, but a realistic estimate of how many could be saved under various shelter programs requiring progressively greater levels of expenditure. Tables 2.13 and 2.14 are an attempt to portray such figures based on a somewhat qualitative, but reasonably careful analysis of the post attack situation resulting from the 4080-MT attack presented.

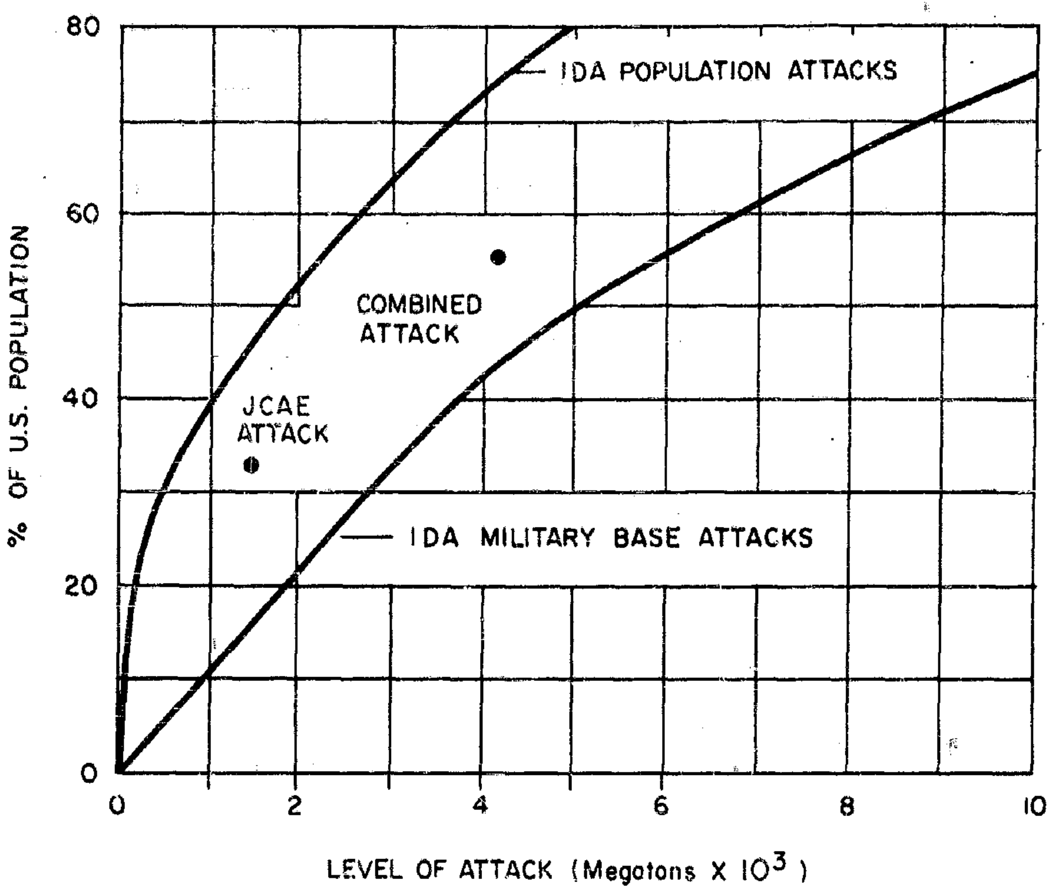


Fig. 2.11 Per Cent of U. S. Casualties As A Function of Various Levels of Attack

TABLE 2.14

ESTIMATE OF CASUALTIES AND SURVIVORS BASED ON DIFFERENT SHELTER PROGRAMS

Target Area Priority Group	Total Population (in millions)	Sq. Miles per 5-MT Weapon Assigned	Blast and Thermal Casualties Per Cent	Blast and Thermal Casualties Population (in millions)	Population in Heavy Fallout Areas (in millions)	Estimate of Survivors (millions) for Shelter Programs Outlined I	II	III	IV	V
1	47	150	80	38	9	–	3	4	1	1
2	15	250	60	9	6	–	2	1	1	2
3	10	500	40	4	6	–	2	1	1	2
4	4	500	20	1	3	–	1	1	–	1
Outside Target Areas	74	—	—	—	35	39	20	3	3	9
Totals	150			52	59	39	28	10	6	15

Total of I through V = 98

The 1960 Census in addition to providing up-to-date population figures, may also include detailed information about home construction, thus making it possible to document the above estimates more precisely.

APPENDIX A

DETAILED COMPARISON BETWEEN THE HOLIFIELD COMMITTEE TARGET LIST AND THAT SHOWN BY THIS REPORT

As noted in Section 2.2.3 comparisons have been made between this report and the targets and weaponage used in three other studies. Of these, the Holifield Committee study was the most complete and most detailed. The total weaponage of this report is not only three times as great but differs in several significant ways from the Holifield study as follows:

1. The large area high priority industrial areas have, in some cases, been assigned six or more times as much weaponage in order to achieve the same level of destruction that is common to both reports for many of the second and third priority industrial areas. The weaponage assigned to Los Angeles, Philadelphia, Chicago and Minneapolis-St. Paul (see Table 2.10) was designed to achieve the levels of industrial destruction that are common to both reports for Washington, Boston and Baltimore.

2. The 19 Atlas, Titan and Minuteman sites recently disclosed in Aviation Week* were probably not identified in unclassified documents at the time the Holifield study was made. However, 15 of the sites were assigned 5- to 10-MT by the Holifield study presumably because of their prior importance as SAC bomber bases. The four SAC bomber and missile bases listed for only one or no weapons in the Holifield study are:

a) Forbes AFB, Topeka, Kan.; 21st Air Div. and Atlas E
b) Beale AFB, Marysville, Calif.; 14th Air Div., Titan I and SAGE
c) Malmstrom AFB, Great Falls, Mont.; 4061 Air Refuel. Wing and Minuteman
d) Larson AFB, Moses Lake, Wash.; 4170 Strategic Wing, Titan I and SAGE

3. The target list developed for this report includes several other groups of targets which do not appear to have been included in the list of the Holifield study, as follows:

a) Nine major industrial areas in southern Canada including, Toronto, Ontario, and Victoria, British Columbia.

* See Reference 12 at the end of this chapter.

b) One second priority (Richmond, Va.) and 14 third priority industrial areas including Charleston, W. Va., Nashville, Tenn., Lansing, Mich., and Tulsa, Okla.

c) The 15 major power and water dams (see Table 2.9).

d) Five state capitals of moderate industrial importance, including Springfield, Ill., and Salt Lake City, Utah.

e) Six SAC bases: Turner AFB, Albany, Ga.
Columbus AFB, Columbus, Miss.
Seymour Johnson AFB, Goldsboro, N.C.
Clinton Sherman AFB, Burns Flat, Okla.
Grand Forks AFB, Grand Forks, N.D.
Glascow AFB, Glascow, Mont.

4. The difference between this report and the Holifield study is further accentuated by the more than 32 targets listed in the latter but not in this report. The three major groups are as follows:

a) Four nuclear fuel or power stations (outside of standard metropolitan areas) such as Richland, Wash., and Aiken, S.C.

b) Five military arsenals or depots such as Redstone Arsenal, Huntsville, Ala., and Pueblo Ordnance Depot, Colo.

c) Twenty-three training and staging camps for military forces including Ft. Benning, Ga., Ft. Bragg, N.C., Parris Island, S.C., Chanute Field, Ill., and ten in Texas (Ft. Hood, Sheppard AFB, Webb, Amarillo and others).

The net fallout effects from the attack of the Holifield study would be significantly less severe but the relative distribution in the various parts of the United States would <u>not</u> be significantly different except in Texas and downwind from Los Angeles, Philadelphia, Chicago and Minneapolis. Fortunately the latter three areas have basement or public building shelter from fallout for most of the population outside the blast levels at either level of attack.

In Texas, however, and possibly in the Los Angeles area the amount and shielding factor of shelter which would be needed might be influenced in different ways by the difference between the attacks of this report and the Holifield study. As is shown in report TO-B 60-30 the available fallout shelter is grossly inadequate even for the lower level attacks on Texas in this report and on Los Angeles in the Holifield study.

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CHAPTER 3

UPPER AIR FALLOUT WINDS OVER THE UNITED STATES

3.1 DESCRIPTION OF WIND PARAMETERS FOR FALLOUT MODELS

A description of the structure of the wind field from the top of the radioactive cloud to the surface is essential to the prediction of radioactive fallout levels. For the purposes of plotting fallout, different agencies employ basic upper wind data in a variety of ways. The fallout model (see Chapter 4) developed by Technical Operations, Incorporated for the Operations Research Office of the Johns Hopkins University* requires the following parameters:

1) The integrated wind vector at different altitudes between the top of the cloud and the surface, and

2) The wind shear between the cloud top and bottom. . Section 3.2 discusses the selection of upper wind belts over the United States, while wind shear is taken up in Section 3.3.

The procedure for integrating the wind effects from a given altitude to the surface is accomplished by determining the wind vector at 5,000-foot intervals and making the assumption that this vector persists throughout the interval. The integrated wind <u>direction</u> is obtained by summing the vectors from the ground to the desired altitude; while the integrated wind <u>speed</u> is the average of the individual wind speeds. At the present time these integrated vectors are recorded in the form of Upper Air Fallout (UF) Winds at 66 Weather Bureau and Military Weather Stations, and are reported twice daily and in the case of some stations, four times daily on the regular Weather Bureau Service "C". These reports give the direction and distance from the Station where particles originating at altitudes of 10, 20, 40, 60 and 80 thousand feet will fall in three hours.

3.2 WIND CHARACTERISTICS OVER THE U. S. BY SEASON

Since the goal of this analysis of the upper winds is to predict the areas where fallout is more likely or less likely to occur, a study of the data over several years

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* Henriques, F. C., and Richards, P. I., "Prediction of Fallout Contours Under Varying Meteorological Conditions", ORO-T-358, TO-2850 (Secret), August 1957.

is necessary before meaningful conclusions can be reached. Sectional and seasonal variations have been analyzed with regard to their effect on the characteristic fallout patterns. To this end, we have made use of a study conducted by the Weather Bureau under contract to OCDM, in which upper wind data collected over a five-year period (March 1951 - February 1956) was surveyed. The results of this survey appear in an unpublished document by Mr. Charles K. Shafer, Radiological Defense Operations Division, OCDM.

The data consist of the daily (1500 GMT) observations at 41 U. S. Weather Bureau stations distributed around the U. S. as shown in Figure 3.1. Table 3.1 summarizes the climatological mean wind direction, D, average speed, S, and standard vector deviation, σ, for each of the four seasons at the 41 stations across the country arranged by OCDM region and state.

A graphical representation of the quantities D, S, and σ, is shown for two sample situations in Figure 3.2. The standard vector deviation, σ, is not itself a true vector, but describes the area within which the end points of 63% of the actual wind vectors would be expected to fall, assuming a normal, circular distribution.* 90% of the vector end points would fall within an area described by a rotating "vector" of length 1.5σ. Although it is recognized that the use of the normal circular distribution implies a known mathematical correlation between variations in wind speed and direction about their mean values, this is not strictly true. The effect of these variations can be described more accurately by an elliptical distribution where the magnitude of the speed and direction variations are measured and plotted separately. However, it turns out in practice that the circular normal distribution is a good approximation to the fact in most cases of interest and was, therefore, used for simplicity.*

Inspection of Table 3.1 reveals that the direction of the winter winds are predominantly from the West at all stations while the summer wind directions present a somewhat more complex pattern. Figures 3.3 and 3.4 show graphically the directions of the mean seasonal winter and summer winds respectively over the country. From Figure 3.4, we see that there is an anti-cyclonic circulation

* "On the Standard Vector Deviation Wind Rose" by Harold L. Crutchen, Journal of Meteorology, February 1957.

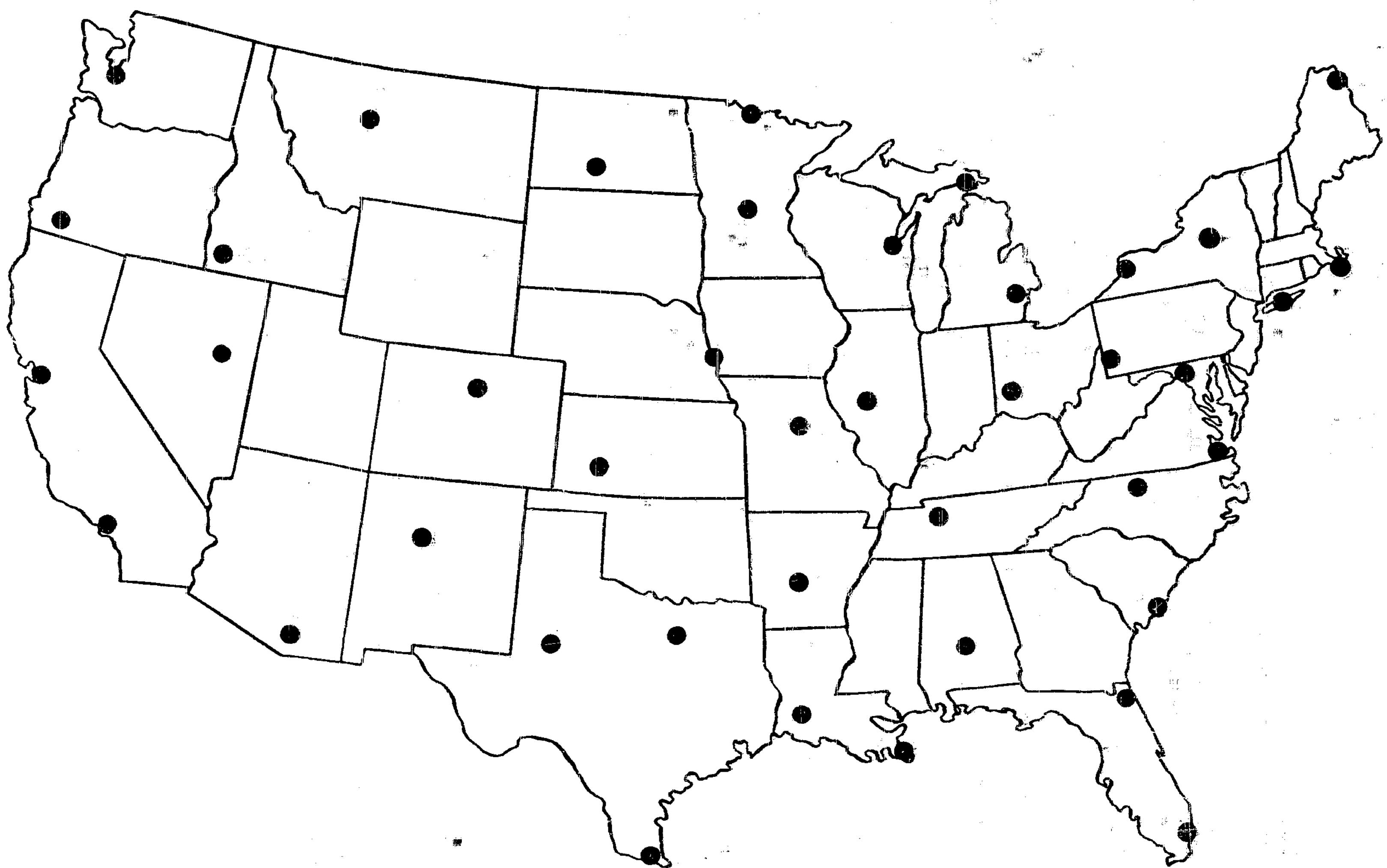


FIGURE 3.1 LOCATION OF 41 WEATHER BUREAU STATIONS FROM WHICH 5-YEAR SURVEY OF UPPER WIND DATA WAS MADE.

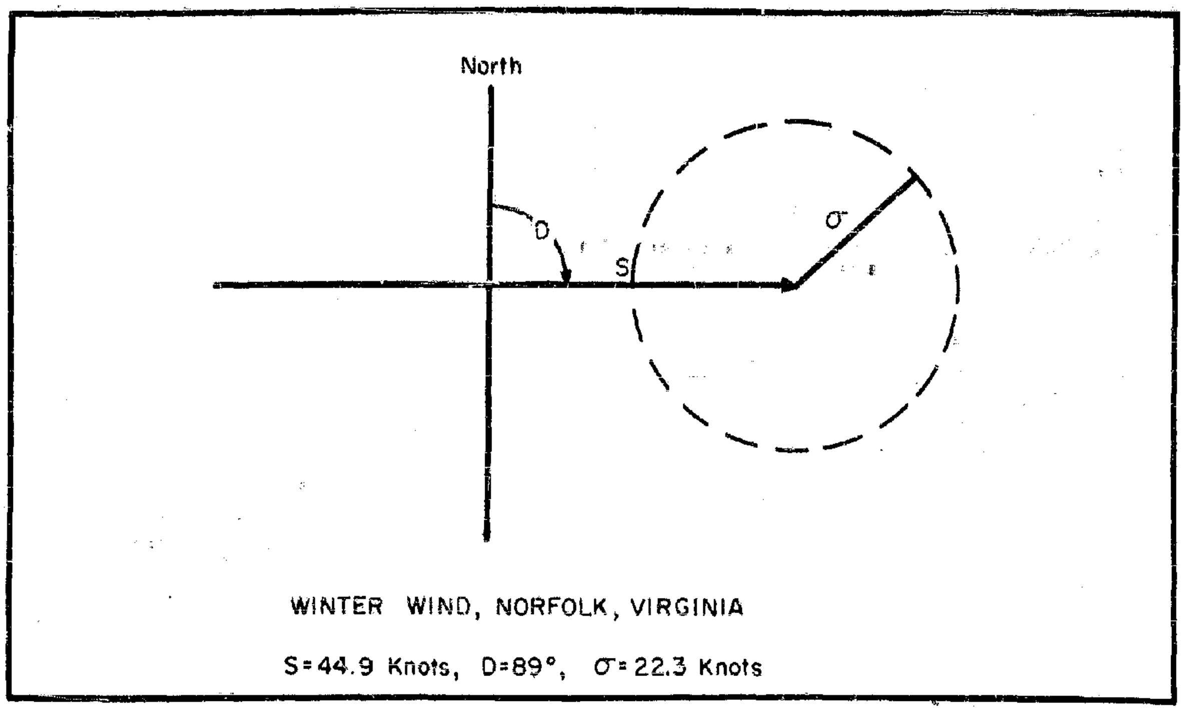
TABLE 3.1

CLIMATOLOGICAL MEAN WIND DIRECTION (D), AVERAGE SPEED (S), AND STANDARD VECTOR DEVIATION (σ) IN THE LAYER FROM 80,000 FOOT ALTITUDE TO THE EARTH SURFACE AT 41 UPPER WIND REPORTING STATIONS

D = direction in degrees clockwise from north
S = speed in knots*
σ = circular normal standard deviation measured in knots

Upper Wind Station	Spring			Summer			Fall			Winter		
OCDM REGION 1	D	S	σ	D	S	σ	D	S	σ	D	S	σ
Caribou, Maine	89	19.0	22.7	93	16.4	18.7	80	29.9	23.3	81	29.7	24.1
Nantucket, Massachusetts	90	29.3	24.3	91	14.6	17.7	77	30.2	23.6	85	42.6	26.2
Hempstead, New York	94	29.0	24.4	104	13.6	16.7	81	29.0	24.2	89	42.7	26.3
Rome, New York	94	26.8	24.2	104	17.0	18.1	81	29.2	23.7	88	37.5	24.4
Buffalo, New York	96	26.3	23.1	107	16.6	16.5	83	28.8	22.6	89	37.4	23.7
OCDM REGION 2												
Washington, D. C.	94	30.5	24.1	112	10.5	16.5	80	26.7	22.9	89	44.7	24.2
Norfolk, Virginia	95	31.0	23.0	124	6.8	15.7	79	23.9	22.9	89	44.9	22.3
Pittsburgh, Pennsylvania	93	29.5	23.7	110	13.1	15.8	83	27.3	22.2	89	43.0	23.6
Dayton, Ohio	92	28.7	23.5	115	11.5	14.9	89	24.9	20.9	90	41.5	26.0
OCDM REGION 3												
Charleston, So. Carolina	92	29.8	22.3	229	3.6	13.6	79	19.0	21.6	88	42.4	19.4
Greensboro, No. Carolina	92	30.2	22.8	137	5.0	14.5	81	22.3	21.5	87	43.4	21.2
Jacksonville, Florida	94	27.7	20.8	253	6.5	12.0	83	16.5	20.7	88	39.0	18.2
Miami, Florida	97	21.8	17.2	267	12.4	10.7	80	6.5	18.4	88	29.5	17.2
Montgomery, Alabama	92	30.7	22.5	246	5.4	13.4	87	18.5	21.5	86	42.2	21.4
Nashville, Tennessee	88	31.2	22.7	146	3.7	13.3	89	22.0	21.2	86	42.7	22.8
OCDM REGION 4												
Columbia, Missouri	87	28.2	22.6	99	8.4	13.4	96	28.8	21.3	91	38.5	25.3
Green Bay, Wisconsin	96	21.7	21.5	105	17.3	16.1	97	26.2	22.1	98	32.4	23.0
Mt. Clemens, Michigan	89	26.2	24.0	109	16.2	16.4	88	26.9	22.3	90	37.0	24.7
Rantoul, Illinois	92	28.2	23.5	110	11.9	14.8	95	25.3	21.4	91	39.0	24.9
Sault Ste. Marie, Michigan	98	19.9	22.0	110	17.7	17.0	95	25.3	22.9	98	30.4	23.5
OCDM REGION 5												
Albuquerque, New Mexico	82	24.9	19.4	35	3.6	13.2	95	17.1	19.5	92	28.9	22.3
Big Spring, Texas	78	30.7	18.7	284	5.3	13.8	93	15.5	20.0	84	35.6	21.2
Brownsville, Texas	78	24.4	15.4	275	12.8	10.7	88	8.2	17.7	77	29.5	16.5
Burrwood, Louisiana	87	28.1	18.7	261	9.5	11.8	88	14.0	19.4	83	37.0	17.8
Fort Worth, Texas	82	31.5	20.4	282	3.7	13.2	95	16.5	20.7	95	37.8	22.3
Lake Charles, Louisiana	83	29.6	19.0	263	8.2	12.1	94	15.3	19.8	82	38.8	19.3
Little Rock, Arkansas	85	31.1	21.8	212	1.9	13.2	96	19.7	20.8	85	40.5	23.2
OCDM REGION 6												
Bismarck, No. Dakota	97	17.1	20.0	85	16.8	15.1	87	23.9	20.5	109	27.8	20.5
Denver, Colorado	90	20.7	20.2	73	10.0	13.6	103	18.6	19.7	104	26.0	22.0
Dodge City, Kansas	83	25.7	20.4	72	6.7	13.1	96	20.8	20.7	93	32.2	23.2
Internat'l Falls, Minnesota	99	16.3	20.2	98	17.8	16.5	106	24.0	21.4	107	27.9	21.2
Omaha, Nebraska	89	19.5	21.5	60	11.2	15.1	93	14.0	20.7	105	25.1	25.6
St. Cloud, Minnesota	95	18.9	21.0	95	17.7	16.8	103	25.2	21.3	103	29.1	22.0
OCDM REGION 7												
Ely, Nevada	95	17.7	20.0	52	12.9	13.0	92	16.9	19.0	102	24.0	23.0
Long Beach, California	93	20.7	20.4	29	7.6	13.2	82	12.7	17.1	101	22.2	23.3
Oakland, California	104	19.5	21.5	60	11.2	15.1	93	14.0	20.7	105	25.1	25.6
Tucson, Arizona	81	26.7	20.2	349	5.1	14.4	85	14.4	18.6	68	27.4	22.7
OCDM REGION 8												
Boise, Idaho	96	16.6	20.0	62	15.7	14.8	97	19.4	20.7	102	25.9	22.9
Great Falls, Montana	95	18.8	19.4	69	16.8	15.3	102	24.1	20.3	106	30.0	21.8
Medford, Oregon	100	18.8	21.2	64	12.0	16.0	92	17.0	22.2	99	26.3	24.3
Seattle, Washington	93	16.6	21.8	76	11.0	18.0	91	21.4	21.8	97	25.7	24.0

* 10 Knots = 11.5 miles per hour.



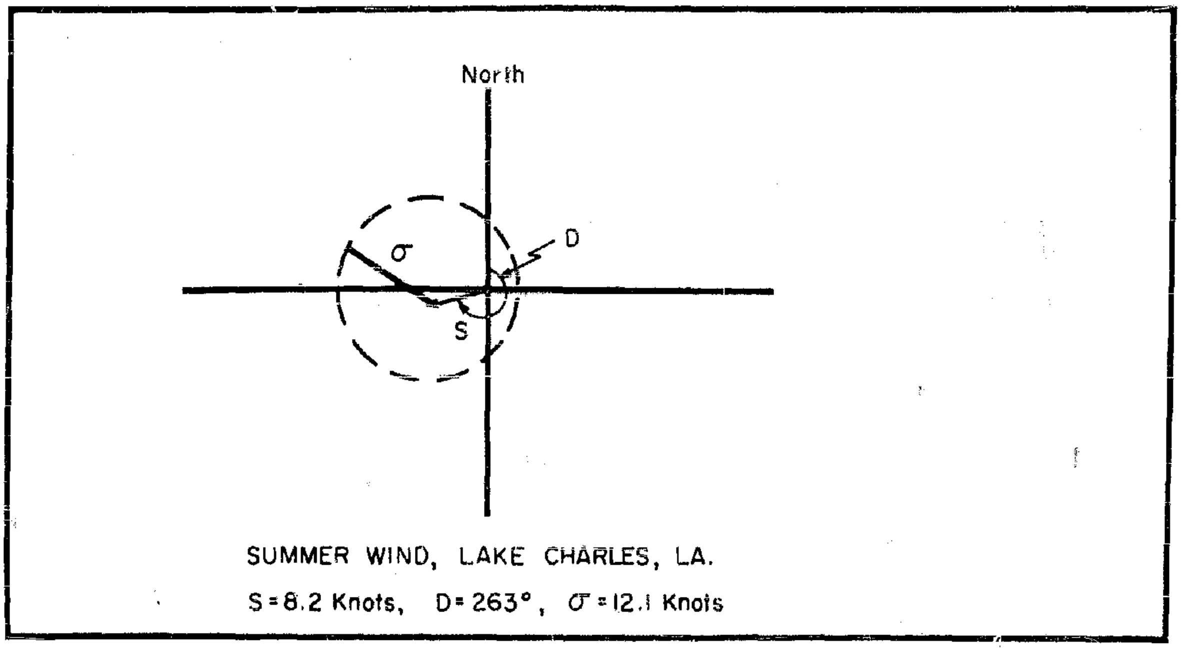


FIGURE 3.2 GRAPHIC REPRESENTATION OF SEASONAL WINDS

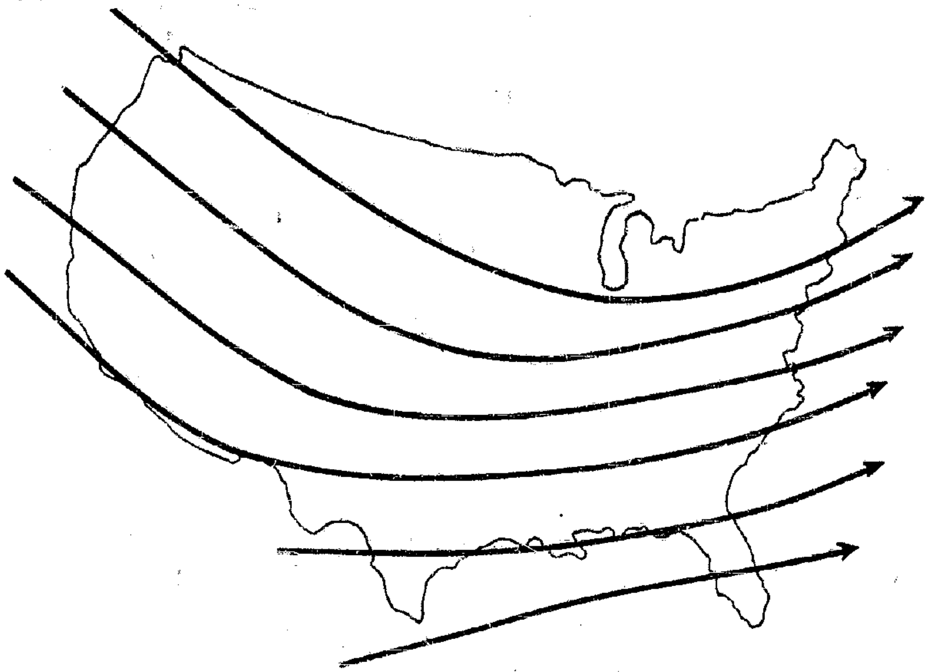


FIGURE 3.3

WINTER MEAN WIND DIRECTION OVER THE U. S.

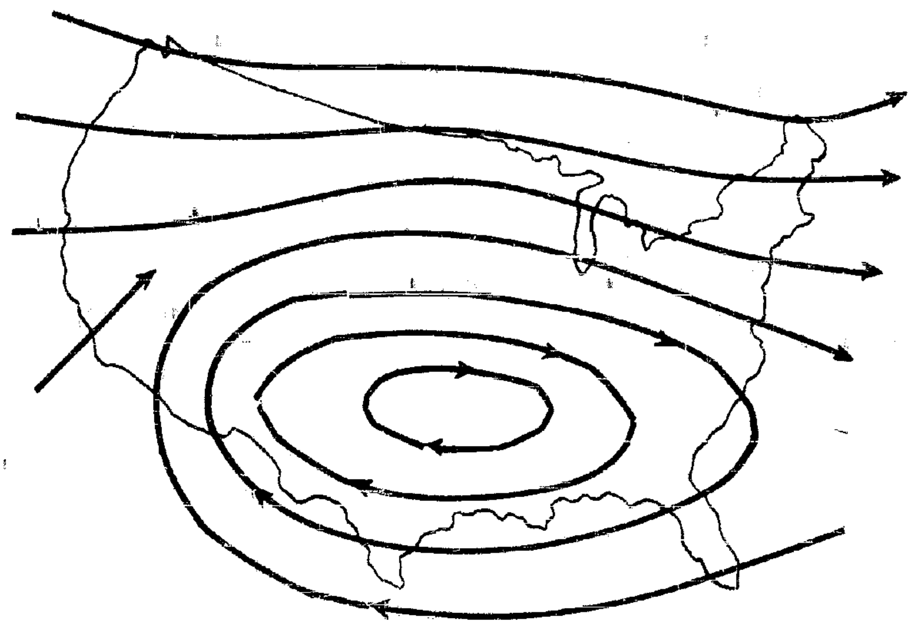


FIGURE 3.4

SUMMER MEAN WIND DIRECTION OVER THE U. S.

centered in the southern part of the U. S. in the summer, with the winds moving in a westerly direction along the Gulf states and easterly north of Oklahoma. In the far southwest, the dominant direction is from the southwest, while in the northeast, the prevailing integrated wind direction is from the west-northwest.

3.3 SELECTION OF WIND SPEED BELTS

With respect to the fallout model, a given pattern can be lined up with any arbitrary wind direction, but the contours change their size and shape as a function of the wind speed and shear; hence different patterns are needed for the different wind speed and shear conditions. A detailed study of Table 3.1 suggested the feasibility of dividing the country into just two wind belts for each season, so that with just two exceptions — the southernmost stations at Miami, Fla., and Brownsville, Texas, there is less than a ten knot difference between the lowest and highest seasonal wind speed within a belt.

Tables 3.2 to 3.5 list the mean 80,000 foot integrated wind speed for the stations in Belts I and II, and the average belt speed for the winter, spring, summer, and fall seasons respectively. Figure 3.5 shows a map of the two wind belts for each season, with a summary of the mean wind speeds for each case. The highest average wind speed is seen to be 46 mph in Winter Belt I, while the lowest is 7 mph in Summer Belt II.

3.4 RELIABILITY OF MEAN SEASONAL WIND DIRECTIONS

Although the shape and size of the fallout pattern are not a function of wind direction, a small change in the direction (i.e., 5 to 10 degrees) can change the predicted fallout radiation level at any given point in the general downwind direction by as much as a factor of four.* In other words, the fallout level at any particular point downwind is very sensitive to the wind direction. Unfortunately, the variations in the 80,000 foot integrated wind direction from day to day and week to week are often quite large. Even in the most reliable areas, the wind direction varies over about a $\pm 30^{\circ}$ range during any one season of the year. In addition, the mean seasonal wind direction in some areas changes very significantly with each season.

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* See Chapter 3, Section 3.4 of Radiological Defense Planning Guide by F. C. Brooks et.al., Report No. TOI 58-26, July 31, 1958.

TABLE 3.2

WINTER FALLOUT WIND BELTS

BELT I		BELT II	
Upper-Wind Station	Mean 80,000 Ft. Integrated Wind Speed (Knots)	Upper-Wind Station	Mean 80,000 Ft. Integrated Wind Speed (Knots)
Norfolk, Virginia	44.9	Green Bay, Wis.	32.4
Washington, D.C.	44.7	Omaha, Neb.	32.3
Greensboro, N. C.	43.4	Dodge City, Kansas	32.2
Pittsburgh, Pa.	43.0	Sault Ste. Marie, Mich.	30.4
Nashville, Tenn.	42.7	Great Falls, Mont.	30.0
Hempstead, N. Y.	42.7	St. Cloud, Minn.	29.1
Nantucket, Mass.	42.6	Albuquerque, N.M.	28.9
Montgomery, Ala.	42.4	Int'l Falls, Minn.	27.9
Charleston, S. C.	42.4	Bismarck, N. D.	27.8
Dayton, Ohio	41.5	Tucson, Arizona	27.4
Little Rock, Ark.	40.5	Medford, Oregon	26.3
Rantoul, Illinois	39.0	Denver, Col.	26.0
Jacksonville, Fla.	39.0	Boise, Idaho	25.9
Lake Charles, La.	38.8	Seattle, Wash.	25.7
Columbia, Mo.	38.5	Oakland, Calif.	25.1
Fort Worth, Texas	37.8	Ely. Nevada	24.0
Rome, N. Y.	37.5	Long Beach, Calif.	22.2
Buffalo, N. Y.	37.4		
Burrwood, La.	37.0	EXCEPTIONS	
Mt. Clemens, Mich.	37.0	Belt I	
Big Springs, Texas	35.6	Caribou, Maine	29.7
		Miami, Fla.	29.5
		Brownsville, Texas	29.5
		Belt II - None	
Average Wind Speed S = 40 ± 5 Knots		Average Wind Speed S = 27 ± 5 Knots	

TABLE 3.3

SPRING FALLOUT WIND BELTS

BELT I		BELT II	
Upper-Wind Station	Mean 80,000 Ft. Integrated Wind Speed (Knots)	Upper-Wind Station	Mean 80,000 Ft. Integrated Wind Speed (Knots)
Fort Worth, Texas	31.5	Green Bay, Wis.	21.7
Nashville, Tenn.	31.2	Denver, Colorado	20.7
Little Rock, Ark.	31.1	Long Beach, Calif.	20.7
Norfolk, Virginia	31.0	Sault Ste. Marie, Mich.	19.9
Big Spring, Texas	30.7	Oakland, Calif.	19.5
Washington, D.C.	30.5	Caribou, Maine	19.0
Greensboro, N. C.	30.2	St. Cloud, Minn.	18.9
Charleston, S. C.	29.8	Great Falls, Mont.	18.8
Lake Charles, La.	29.6	Medford, Oregon	18.8
Pittsburgh, Pa.	29.5	Ely, Nevada	17.7
Nantucket, Mass.	29.3	Bismarck, N. D.	17.1
Hempstead, N. Y.	29.0	Seattle, Wash.	16.8
Dayton, Ohio	28.7	Boise, Idaho	16.6
Rantoul, Illinois	28.2	Int'l. Falls, Minn.	16.3
Columbia, Mo.	28.2		
Burrwood, La.	28.1		
Jacksonville, Fla.	27.7		
Rome, N. Y.	26.8		
Tucson, Arizona	26.7		
Buffalo, N. Y.	26.3		
Mt. Clemens, Mich.	26.2		
Dodge City, Kan.	25.7		
Albuquerque, N. M.	24.9		
Brownsville, Texas	24.4		
Omaha, Neb.	24.2		
Average Wind Speed S = 28 ± 4 Knots		Average Wind Speed S = 19 ± 3 Knots	

EXCEPTIONS

Belt I	
Miami, Fla.	21.8
Montgomery, Ala.	20.7
Belt II - None	

TABLE 3.4

SUMMER FALLOUT WIND BELTS

BELT I		BELT II	
Upper-Wind Station	Mean 80,000 Ft. Integrated Wind Speed (Knots)	Upper-Wind Station	Mean 80,000 Ft. Integrated Wind Speed (Knots)
Int'l. Falls, Minn.	17.8	Burrwood, La.	9.5
St. Cloud, Minn.	17.7	Columbia, Mo.	8.4
Green Bay, Wis.	17.3	Lake Charles, La.	8.2
Rome, N. Y.	17.0	Long Beach, Calif.	7.6
Great Falls, Mont.	16.8	Norfolk, Virginia	6.8
Bismarck, N. D.	16.8	Dodge City, Kan.	6.7
Buffalo, N. Y.	16.6	Jacksonville, Fla.	6.5
Caribou, Maine	16.4	Montgomery, Ala.	5.4
Mt. Clemens, Mich.	16.2	Big Spring, Texas	5.3
Boise, Idaho	15.7	Tucson, Arizona	5.1
Nantucket, Mass.	14.6	Greensboro, N. C.	5.0
Hempstead, N. Y.	13.6	Nashville, Tenn.	3.7
Pittsburgh, Pa.	13.1	Fort Worth, Texas	3.7
Ely, Nevada	12.9	Albuquerque, N. M.	3.6
Medford, Oregon	12.0	Charleston, S. C.	3.6
Rantoul, Ill.	11.9	Little Rock, Ark.	1.9
Omaha, Neb.	11.8		
Dayton, Ohio	11.5	EXCEPTIONS	
Oakland, Calif.	11.2	Belt I - None	
Seattle, Wash.	11.0	Belt II	
Washington, D.C.	10.5	Brownsville, Texas	12.8
Denver, Colorado	10.0	Miami, Florida	12.4
Average Wind Speed S = 14 ± 4 Knots		Average Wind Speed S = 6 ± 4 Knots	

TABLE 3.5

FALL FALLOUT WIND BELTS

BELT I		BELT II	
Upper-Wind Station	Mean 80,000 Ft. Integrated Wind Speed (Knots)	Upper-Wind Station	Mean 80,000 Ft. Integrated Wind Speed (Knots)
Nantucket, Mass.	30.3	Dodge City, Kan.	20.8
Caribou, Maine	29.9	Little Rock, Ark.	19.7
Rome, N. Y.	29.2	Boise, Idaho	19.4
Hempstead, N. Y.	29.0	Medford, Oregon	19.0
Buffalo, N. Y.	28.8	Charleston, S. C.	19.0
Pittsburgh, Pa.	27.3	Denver, Colorado	18.6
Mt. Clemens, Mich.	26.9	Montgomery, Ala.	18.5
Washington, D.C.	26.7	Nashville, Tenn.	18.5
Green Bay, Wis.	26.2	Albuquerque, N. M.	17.1
Sault Ste. Marie, Mich.	25.3	Ely, Nevada	16.9
Rantoul, Illinois	25.3	Jacksonville, Fla.	16.5
St. Cloud, Minn.	25.2	Fort Worth, Texas	16.5
Dayton, Ohio	24.9	Big Spring, Texas	15.5
Omaha, Nebraska	24.2	Lake Charles, La.	15.3
Great Falls, Mont.	24.1	Tucson, Arizona	14.4
Int'l. Falls, Minn.	24.0	Oakland, Calif.	14.0
Norfolk, Virginia	23.9	Burrwood, La.	14.0
Bismarck, N. D.	23.9	Long Beach, Calif.	12.7
Columbia, Mo.	23.8		
Greensboro, N. C.	22.3		
Seattle, Wash.	21.4		

EXCEPTIONS

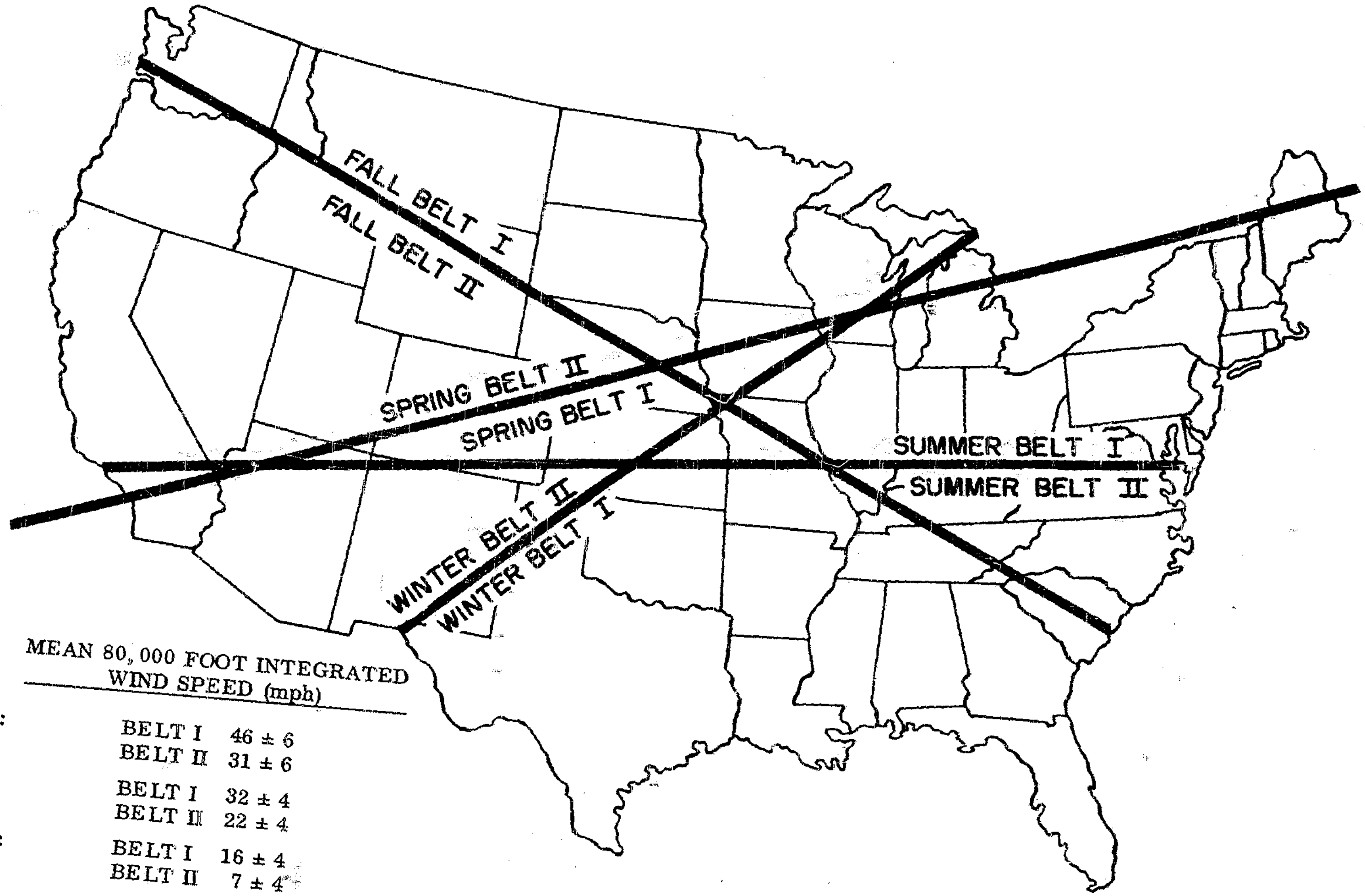
Belt I - None

Belt II

Brownsville, Texas	8.2
Miami, Florida	6.5

Average Wind Speed S = 26 ± 4 Knots (Belt I)

Average Wind Speed S = 17 ± 4 Knots (Belt II)



SEASON		MEAN 80,000 FOOT INTEGRATED WIND SPEED (mph)
WINTER:	BELT I	46 ± 6
	BELT II	31 ± 6
SPRING:	BELT I	32 ± 4
	BELT II	22 ± 4
SUMMER:	BELT I	16 ± 4
	BELT II	7 ± 4
FALL:	BELT I	30 ± 4
	BELT II	20 ± 4

FIGURE 3.5 SEASONAL WIND BELTS FOR THE U.S.

To get a quantitative picture of the seasonal reliability of wind directions over the U. S., the ratio of the standard vector deviation, σ, to the average wind speed, S, for winter and summer winds was determined for the 41 stations listed in Table 3.1. The stations were then listed in order of decreasing wind directional reliability, and classified into three categories as follows:

Reliability Category	σ/S
Good	0.4 to 0.8
Fair	0.8 to 1.2
Poor	greater than 1.2

Figure 3.6 shows graphically the different degrees of wind reliability. The standard vector deviation, σ, actually measures speed variability as well as directional variability; however, we are interested at this point only in the directional variations due to the much greater sensitivity of the fallout pattern to this parameter. From Figure 3.6 we see that good reliability implies a "one σ" directional variation of about $\pm 35^{\circ}$, fair reliability implies a variation approaching $\pm 90^{\circ}$, while poor reliability results in a significant probability of the wind being in any direction, (though the speed will generally be much lower when the actual direction is opposite to the mean direction).

The σ/S "reliability" ratio for all stations is listed in Table 3.6 for the winter and summer winds. In the winter, we see that all stations are in either the "good" or "fair" category, while the summer winds are either "fair" or "poor". Figure 3.7 shows the over-all situation on a map of the U. S. In summary, winter directional reliability is good over the eastern two-thirds of the country, and fair over the western third. Summer reliability is fair over the northern 40% of the U. S., and poor over most of the remaining 60% except for the southern part of Florida and Texas where it improves almost to the "good" category. On an annual basis, then, the best situation exists over the northeast and north central states which have a "winter-good; summer-fair" rating. The next best areas are the northwest with a "winter-fair; summer-fair" rating, and southeast with a "winter-good; summer-poor" situation. The poorest area is the southwest which falls into the "winter-fair; summer-poor" category.

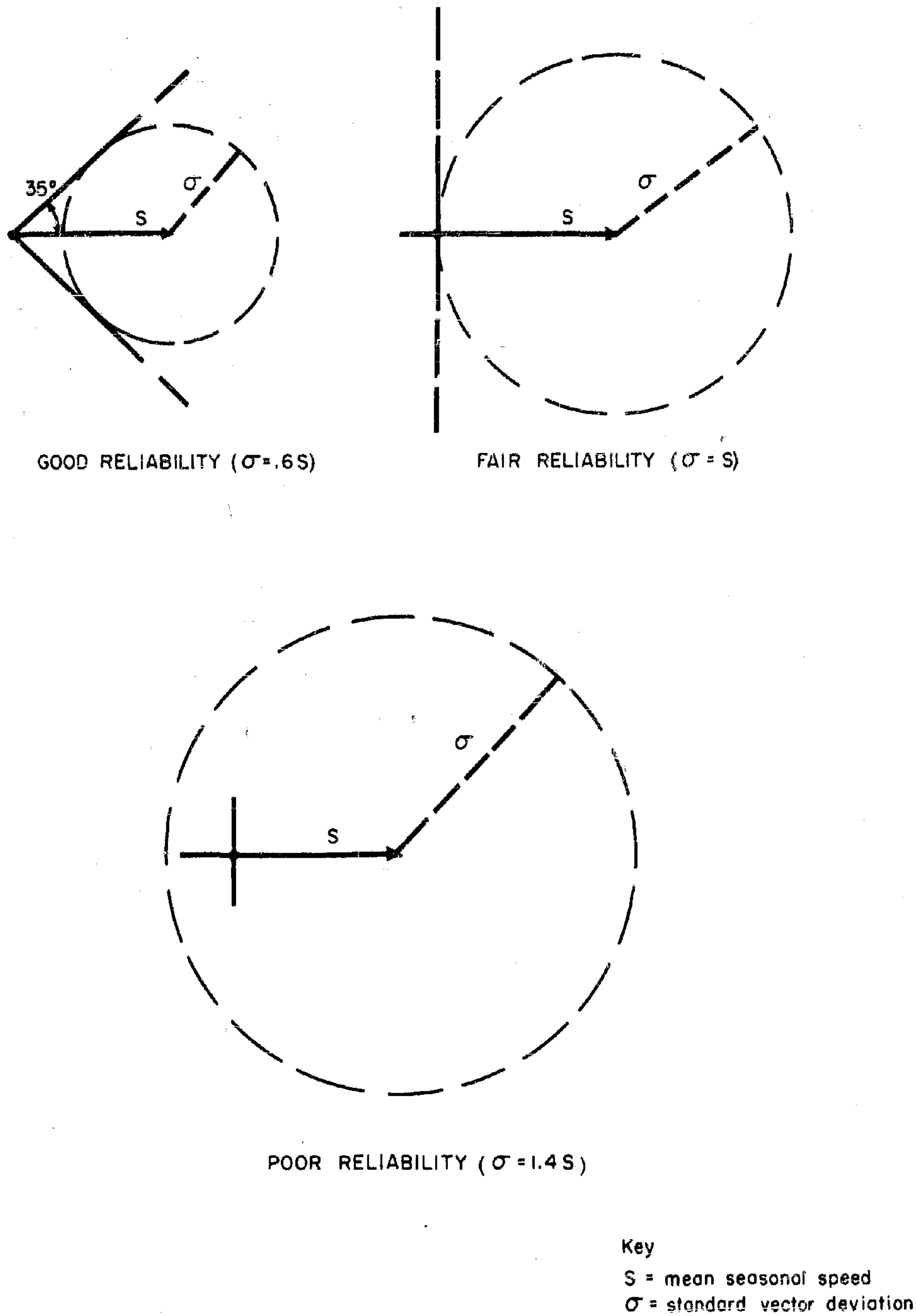


FIGURE 3.6 DIAGRAM SHOWING DIFFERENT DEGREES OF WIND RELIABILITY (End Point of Wind Vectors Fall Within Circle 63% of the Time)

TABLE 3.6

RATIO OF STANDARD VECTOR DEVIATION TO AVERAGE WIND SPEED (σ/S) FOR WINTER WINDS

WIND DIRECTIONAL RELIABILITY					
GOOD ($0.4 < \sigma/S < 0.8$)		FAIR ($0.8 < \sigma/S < 1.2$)		POOR ($\sigma/S > 1.2$)	
UPPER WIND STATION	σ/S	UPPER WIND STATION	σ/S	UPPER WIND STATION	σ/S
WINTER		WINTER		WINTER	
Charleston, S. C.	.46	Caribou, Me.	.81	None	
Jacksonville, Fla.	.47	Tucson, Ariz.	.83	SUMMER	
Burrwood, La.	.48	Denver, Colo.	.85	Nantucket, Mass.	1.21
Greensboro, N. C.	.49	Boise, Idaho	.89	Pittsburgh, Pa.	1.21
Norfolk, Va.	.50	Medford, Oregon	.92	Hempstead, N. Y.	1.23
Lake Charles, La.	.50	Seattle, Wash.	.93	Burrwood, La.	1.24
Montgomery, Ala.	.51	Ely, Nev.	.96	Rantoul, Ill.	1.24
Nashville, Tenn.	.53	Oakland, Cal.	1.02	Dayton, Ohio	1.30
Washington, D. C.	.55	Long Beach, Cal.	1.05	Medford, Oregon	1.33
Pittsburgh, Pa.	.55	Total = 9 stations		Oakland, Cal.	1.35
Brownsville, Tex.	.56	SUMMER		Denver, Colo.	1.35
Little Rock, Ark.	.57	Brownsville, Tex.	.84	Lake Charles, La.	1.48
Miami, Fla.	.58	Miami, Fla.	.86	Washington, D. C.	1.57
Hempstead, N. Y.	.59	Bismarck, N. D.	.90	Columbia, Mo.	1.60
Fort Worth, Tex.	.59	Great Falls, Mont.	.91	Seattle, Wash.	1.64
Big Spring, Tex.	.60	Green Bay, Wis.	.93	Long Beach, Cal.	1.74
Nantucket, Mass.	.61	Internat'l Falls, Minn.	.93	Jacksonville, Fla.	1.85
Dayton, Ohio	.63	Boise, Idaho	.94	Dodge City, Kan.	1.96
Buffalo, N. Y.	.63	St. Cloud, Minn.	.95	Norfolk, Va.	2.31
Rantoul, Ill.	.64	Sault Ste. Marie, Mich.	.96	Montgomery, Ala.	2.48
Rome, N. Y.	.65	Buffalo, N. Y.	.99	Big Spring, Tex.	2.52
Columbia, Mo.	.66	Ely, Nev.	1.00	Tucson, Ariz.	2.82
Mt. Clemens, Mich.	.67	Mt. Clemens, Mich.	1.01	Greensboro, N. C.	2.90
Green Bay, Wis.	.71	Rome, N. Y.	1.06	Fort Worth Texas.	3.50
Omaha, Neb.	.71	Caribou, Me.	1.14	Nashville, Tenn.	3.59
Dodge City, Kan.	.72	Omaha, Neb.	1.18	Albuquerque, N. M.	3.70
Bismarck, N. D.	.74	Total = 15 stations		Charleston, S. C.	3.78
Internat'l Falls, Minn.	.76			Little Rock, Ark.	7.94
St. Cloud, Minn.	.76			Total = 26 stations	
Sault Ste. Marie, Mich.	.77				
Albuquerque, N. M.	.77				
Great Falls, Mont.	.78				
Total = 32 stations					
SUMMER					
None					

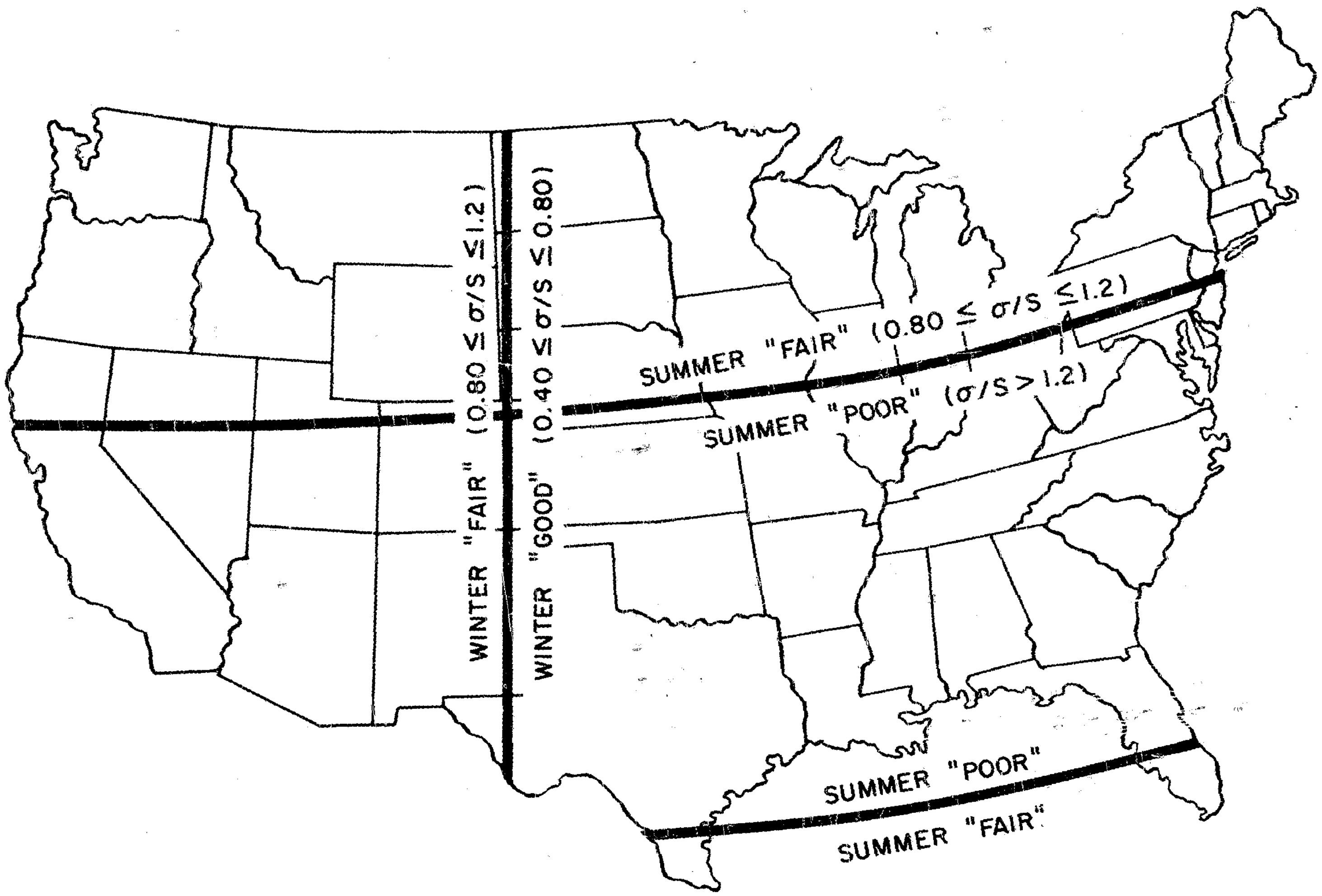


FIGURE 3.7 RELIABILITY OF SEASONAL WIND DIRECTION FOR WINTER AND SUMMER OVER THE U. S.

3.5 MEAN ANNUAL WIND DIRECTIONS AND RANGE OF MEAN SEASONAL WINDS

In planning the location of stockpiles, communications and control centers, new fallout shelters, etc., it would be ideal if the mean annual wind direction could be used as a reliable indicator of the most likely high and low fallout areas, rather than have to make different plans on the basis of each seasonal wind pattern. Of course, where the seasonal reliability is poor, as it is for some 20 southern states in the summer (see Figure 3.7), it becomes almost meaningless to think in terms of a preferred direction for planning purposes; however, in the 18 northeast and central states where the seasonal reliability is good in the winter and fair in summer, it would be well worthwhile to talk in terms of a preferred annual direction, provided the range of the four mean seasonal winds is small enough so as not to seriously degrade the seasonal reliability.

Table 3.7 lists the range of the four mean seasonal wind directions in order of increasing range for the 41 stations used in the five-year survey; the mean annual wind direction is also given. The spread between stations is striking — from a range of about 10° (i.e., $\pm 5^{\circ}$) over the year in the Minnesota and Wisconsin area to a range of 200° in Texas! In relation to the seasonal reliability diagrams in Figure 3.6, it was determined that superimposing a mean seasonal direction range of less than 30° would not significantly degrade the seasonal reliability ratings, and that a range of between 30° and 60° would still not render them unusable. Hence, in areas having less than a 30° range, the annual mean direction is categorized as being "good", a 30° to 60° range has been labelled "fair", while a range greater than 60° is considered "poor". Figure 3.8 shows the areas of the U. S. in each category. It is indeed fortunate that the best area of the country from the standpoint of seasonal reliability (see Figure 3.7) is also the same area where the range of mean directions from season to season is good (i.e., less than 30°). Therefore, in the case of the 18 northeast and central states, the mean annual wind direction gives a good reliable indication of the wind direction at any time throughout the year, and only occasionally would we expect the observed wind direction to be more than about $\pm 45^{\circ}$ from the mean annual direction. For the five northwestern states, the wind direction would not be expected to deviate by more than $\pm 90^{\circ}$ very often, while for the rest of the country, the deviations are too great to make any serious use of a preferred annual direction for planning purpose.

TABLE 3.7

ANNUAL WIND DIRECTIONAL RELIABILITY

GOOD (Range < 30°)			FAIR (Range between 30° and 60°)			POOR (Range > 60°)		
UPPER WIND STATION	Mean annual wind direction (degrees from North)	Range of mean seasonal wind directions (degrees)	UPPER WIND STATION	Mean annual wind direction (degrees from North)	Range of mean seasonal wind directions (degrees)	UPPER WIND STATION	Mean annual wind direction (degrees from North)	Range of mean seasonal wind directions (degrees)
St. Cloud, Minn.	101	8	Denver, Colo.	97	30	Tucson, Ariz.	78	99
Internat'l Falls, Minn.	104	9	Washington, D. C.	89	32	Little Rock, Ark.	89	127
Green Bay, Wis.	99	9	Medford, Oregon	92	36	Charleston, S. C.	89	150
Omaha, Neb.	97	11	Great Falls, Mont.	98	37	Montgomery, Ala.	91	160
Columbia, Mo.	92	12	Boise, Idaho	92	40	Jacksonville, Fla.	90	170
Caribou, Me.	84	13	Oakland, Cal.	96	45	Burrwood, La.	86	178
Nantucket, Mass.	85	14	Norfolk, Va.	89	45	Lake Charles, La.	85	181
Sault Ste. Marie, Mich.	100	15	Long Beach, Cal.	98	47	Miami, Fla.	92	187
Rantoul, Ill.	96	19	Ely, Nevada	89	50	Brownsville, Tex.	75	198
Seattle, Wash.	92	21	Greensboro, N. C.	90	56	Ft. Worth, Tex.	87	200
Mt. Clemens, Mich.	93	21	Nashville, Tenn.	89	60	Big Spring, Tex.	84	206
Hempstead, N. Y.	90	23	Albuquerque, N.M.	87	60	Total = 11 stations		
Rome, N. Y.	90	23	Total = 12 stations					
Dodge City, Kan.	90	24						
Bismarck, N. D.	95	24						
Buffalo, N. Y.	92	24						
Dayton, Ohio	92	26						
Pittsburgh, Pa.	92	27						
Total = 18 stations								

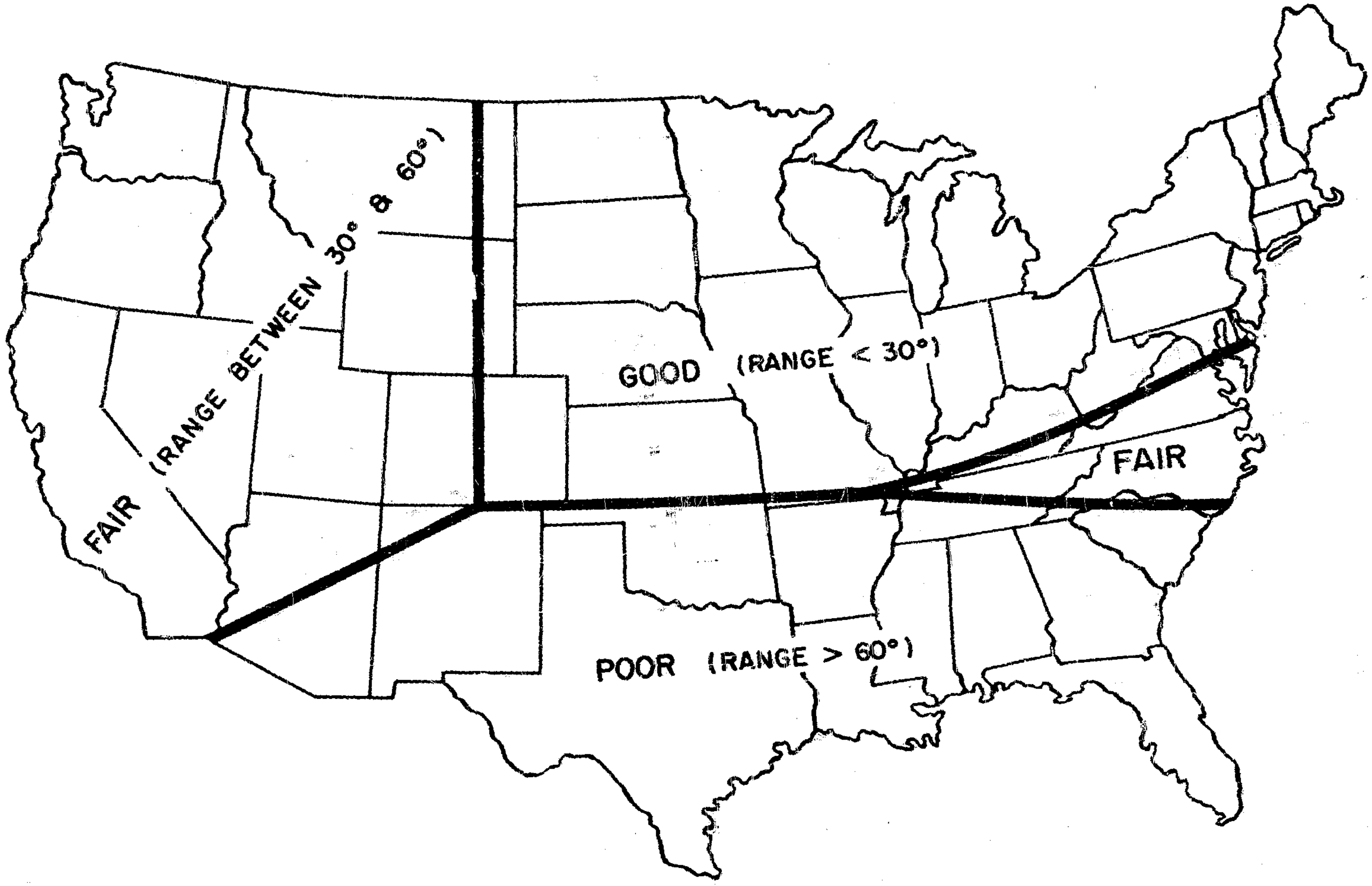


FIGURE 3.8 - RANGE OF THE FOUR MEAN SEASONAL WIND DIRECTIONS OVER THE U. S.

3.6 WIND SHEAR

For the purposes of the Tech/Ops fallout model, wind shear is defined as the maximum angle subtended by the fall points of all the 100 micron particles originating within the radioactive cloud. This angle, which is a function of the change in the direction of the wind throughout the cloud, determines the width of the fallout pattern. Wind shear is found for a single wind condition by plotting the positions on the ground of the 100 micron particles that originate within the cloud. In this method, the wind vectors at specific altitudes are important, and the information generally used are the wind vectors at 5,000 foot intervals throughout the cloud.

There is no comparable data available to allow making a wind shear investigation over the U. S. similar to the one of the previous sections on wind direction and speed. Recently, however, the Weather Bureau has made an attempt to correlate wind speed and wind shear.* In their study, wind shear is defined as the angle between the 40,000 foot and 80,000 foot UF vectors. The speed chosen was the 70,000 foot UF wind speed (found by interpolating between the 60,000 foot and 80,000 foot UF vectors available from the regular UF data files). The figure of 70,000 feet was undoubtedly chosen because it is the mean pressure altitude for weapons of 5-MT yield or greater (see Figure 4.3). The UF data used consisted of 5,682 observations made during the summer and 2,199 observations during the winter of 1957 throughout all parts of the U. S. The preliminary results of this study are shown on Figure 3.9.

It should be noted that wind shear as defined in the Weather Bureau study is not exactly the same as that used in the Tech/Ops model for a 5-MT weapon. For example, the cloud bottom and top for a 5-MT weapon are 55,000 feet and 90,000 feet respectively (see Figure 4.3) as opposed to the 40,000 foot to 80,000 foot range for which the Weather Bureau shear was calculated. In addition, wind shear between 40,000 to 80,000 feet does not always produce the largest angle difference between these two elevations for the fall-points of all the 100 micron particles, since the wind may not change continuously in one direction from the lowest to the highest altitude considered. Thus, an altitude somewhere in between will sometimes produce the side of the wind shear angle as defined by the model. The net effect of these differences is estimated to add about 10% to the wind shear as defined by the

* Preliminary results of an unpublished study obtained from Leo R. Quenneville, Meteorologist, Special Projects Section, Office of Meteorological Research, Weather Bureau, Washington, D. C., August 1959.

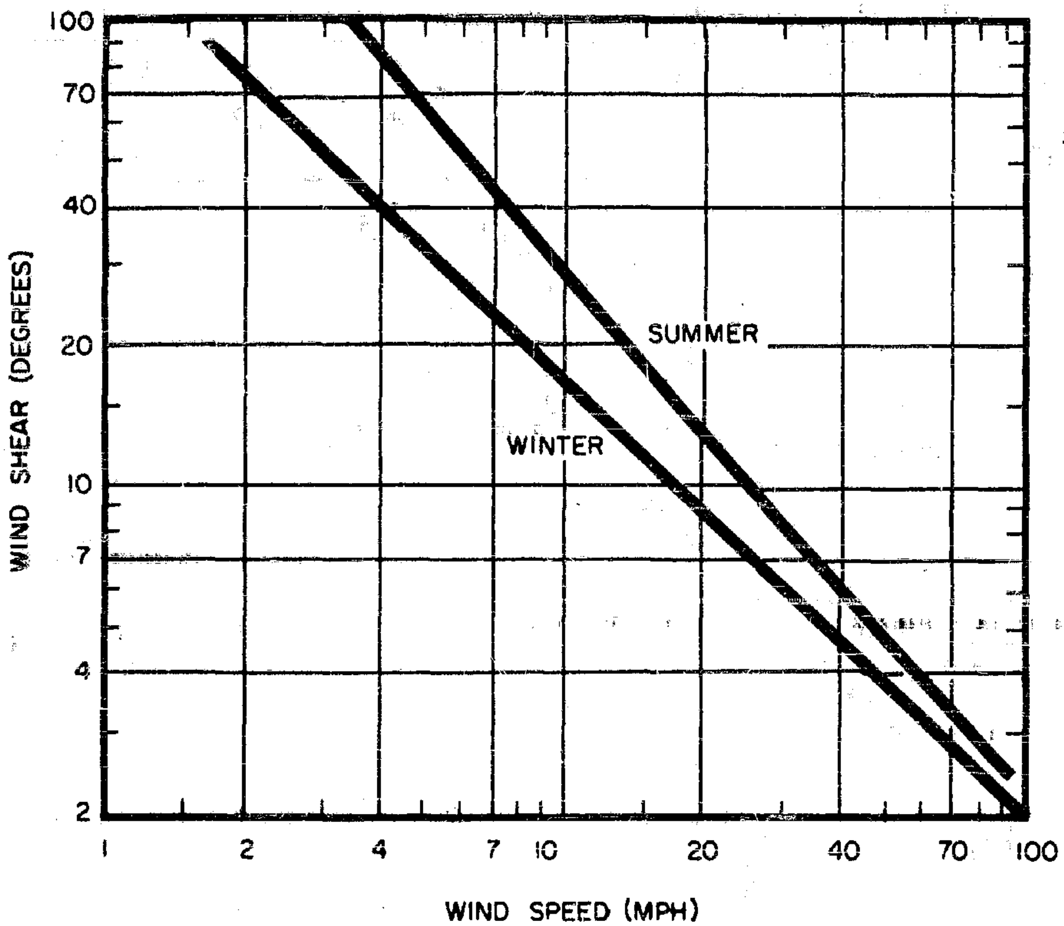


FIGURE 3.9

RELATION BETWEEN UPPER AIR
WIND SHEAR AND WIND SPEED

(SHEAR = Angle between the 40,000 ft. and 80,000 ft. integrated wind vector.)

(SPEED = 70,000 ft. integrated wind speed)

Weather Bureau study. In addition to the calculated wind shear (in degrees), a shear category is also used in the fallout model of Chapter 4. The three shear categories are defined as follows:

Shear Category	Degree of Wind Shear
Low	less than 25°
Moderate	25° to 65°
High	greater than 65°

Using Figure 3.9 in conjunction with the above, a wind shear (and shear category) was found for each of the wind speed belts shown in Figure 3.5. The results are tabulated in Table 3.8.

TABLE 3.8

WIND SHEAR ASSOCIATED WITH WIND SPEED BELTS

Wind Belt	Average Wind Speed (mph)	Wind Shear (degrees)	Wind Shear (category)
Winter - Belt I	46	5	Low
Winter - Belt II	31	7	Low
Spring - Belt I	32	8	Low
Spring - Belt II	22	12	Low
Summer - Belt I	16	20	Low
Summer - Belt II	7	48	Moderate
Fall - Belt I	30	8	Low
Fall - Belt II	20	12	Low

REFERENCES

1. "Fallout and the Winds", Civil Defense Technical Bulletin, No. TB-11-21, February 1956.

2. Knox, Joseph B., "Graphical Methods for Quantitative Prediction of Close-In Fallout", The Rand Corp., January 31, 1958.

3. Glasstone, Samuel, ed., "The Effects of Nuclear Weapons", published by AEC, June 1957.

4. Henriques, F. C., and Richards, P. I., "Prediction of Fallout Contours Under Varying Meteorological Conditions", ORO-T-358, TO-2850 (Secret), August 1957.

5. "Probability of Fallout Debris Deposition", Civil Defense Technical Bulletin, No. TB-11-31, June 1957.

6. "Close-In Fallout", The Rand Corp., Report No. 309, September 30, 1957.

7. "Winds and Fallout, A Climatological Appraisal", U. S. Weather Bureau, June 1955.

8. Kellogg, W. W., Rapp, R. R., and Greenfield, S. M., "Close-In Fallout", Journal of Meteorology, Vol. 14, No. 1, February 1957.

9. "Construction and Use of Area Fallout Plots from Routine United States Weather Bureau Forecasts (UF)", FCDA Advisory Bulletin, No. 188 Revised, January 24, 1958.

CHAPTER 4

FALLOUT CONTOURS

4.1 INTRODUCTION

It is assumed that an enemy attack over the continental United States would be confined for the most part to nuclear surface bursts of megaton size rather than air bursts. Under these conditions a large crater would be formed under the detonation and the particles representing the displaced volume of earth would become radioactivated as the pressure and temperature of the burst sends them in vertical motion and distributes them throughout the mushroom cloud. The cloud appears to stabilize about ten minutes after the burst, after which time gravitational and meteorological forces start to dominate the behavior of the cloud particles. The heavier particles fall nearer ground zero while the lighter ones are distributed at various distances downwind depending, to a large degree, upon the wind field from the top of the cloud to the ground.

The final position on the ground of the radioactive particles (and hence the fallout levels at any point) is determined by a large number of physical parameters, the most important of which appear to be:

1) Weapon size (which determines the cloud height and dimensions).
2) Particle size distribution in the cloud.
3) Wind field from the top of the cloud to the ground.
4) Radioactivity associated with the different particle sizes.

All the fallout models which have been proposed by various agencies during the past several years[1] are hampered by the lack of good experimental data, particularly for the megaton-size weapons. The model, therefore, must be based on a variety of assumptions that seem plausible in the absence of knowledge about the real situation.

To develop manageable computation procedures, it is further necessary to make several simplifying assumptions about the particle distribution, cloud shape, and wind field. Without these assumptions, the computations, which could be readily carried out on a digital computer, become too lengthy for a fallout model designed for hand-computation.

* "The Nature of Radioactive Fallout and Its Effect on Man", Congressional Hearings Before the Special Subcommittee on Radiation, May 27-June 3, 1957, Part I, pp. 104-118.

Fallout contours can be generated to give isointensity levels referred to some arbitrary time (generally one hour) after the burst, or isodose levels which integrate the intensity from fallout arrival to some arbitrary time, frequently taken to be 48 hours after the detonation. The discussion in the next section describes the development of fallout patterns which give the two-day cumulative dose. We prefer to work with these dose patterns as opposed to the dose rate contours for the reasons stated in Chapter 2 of the Radiological Defense Planning Guide.[2]

4.2 DESCRIPTION OF THE "TECH/OPS" FALLOUT MODEL[3]

As previously stated, due to the paucity of good experimental data, a set of basic physical assumptions had to be made for the model. Certain other assumptions were made so that a computer solution would not be required. An outline of these two types of assumptions used in developing the model follow.

4.2.1 Assumptions and Method of Development

4.2.1.1 Basic Physical Assumptions

The following is a list and brief discussion of the most important basic physical parameters about which assumptions had to be made in the absence of good experimental data:

Assumption No. 1 The cloud appears to stabilize about ten minutes after the burst, and the fallout computations begin at this hypothetical instant of stabilization.

This assumption has been common to practically all models in present use; the one notable exception is a new model recently developed at the Naval Radiological Defense Laboratory in which the calculations involving particle motions begin at the instant the fireball reaches its full dimensions. This is a matter of only about 50 seconds after the detonation of a 10-MT weapon, and 4 seconds for a 10-KT burst. The particles are then assumed to move in accordance with the net effect of the cloud's vertical motion and the action of gravity. Hence, the particles

(2) Radiological Defense Planning Guide, Report No. TOI-58-26, July 31, 1958.
(3) Henriques, F. C., and Richards, P. I., "Prediction of Fallout Contours Under Varying Meteorological Conditions", ORO-T-358, TO-2850 (Secret), August 1957.

immediately start to drop relative to the cloud as soon as it begins to rise, and for the smaller weapons, at least (kiloton size), the model indicates that a significant fraction of the radioactive particles are no longer in the cloud at the "instant of stabilization". The model has been checked with reasonably good results against some of the observed patterns from weapons tests, but lack of good experimental data still make it very difficult to get a reliable check for the megaton size weapons.

Assumption No. 2 The radioactivity in the cloud is distributed lognormally with respect to particle size as shown in Figure 4.1.

This curve is based on data taken at various weapons tests by the Naval Radiological Defense Laboratory. No data is available from a surface burst of a megaton size weapon detonated on a continental land mass, and since the activity and particle size distribution are believed to be quite different for continental land masses composed of silicon material as compared to coral land masses of the Pacific islands, the curve shown in Figure 4.1 is just a "best guess" based on data which may or may not be a good approximation to the real life situation of primary interest.

According to testimony given before the Holifield special subcommittee on radiation[1], "Both observation of the particles, collected in many ways in the Pacific and in Nevada, and theoretical calculations of the way in which they must fall, indicated that the majority of the particles taking part in the close-in fallout have diameters between about 50 and 400 microns." From Figure 4.1, we note that particle sizes of 50 and 400 microns represent approximately the 25% and 75% points respectively on the curve, implying that about 50% of the total activity lies between these particle size limits.

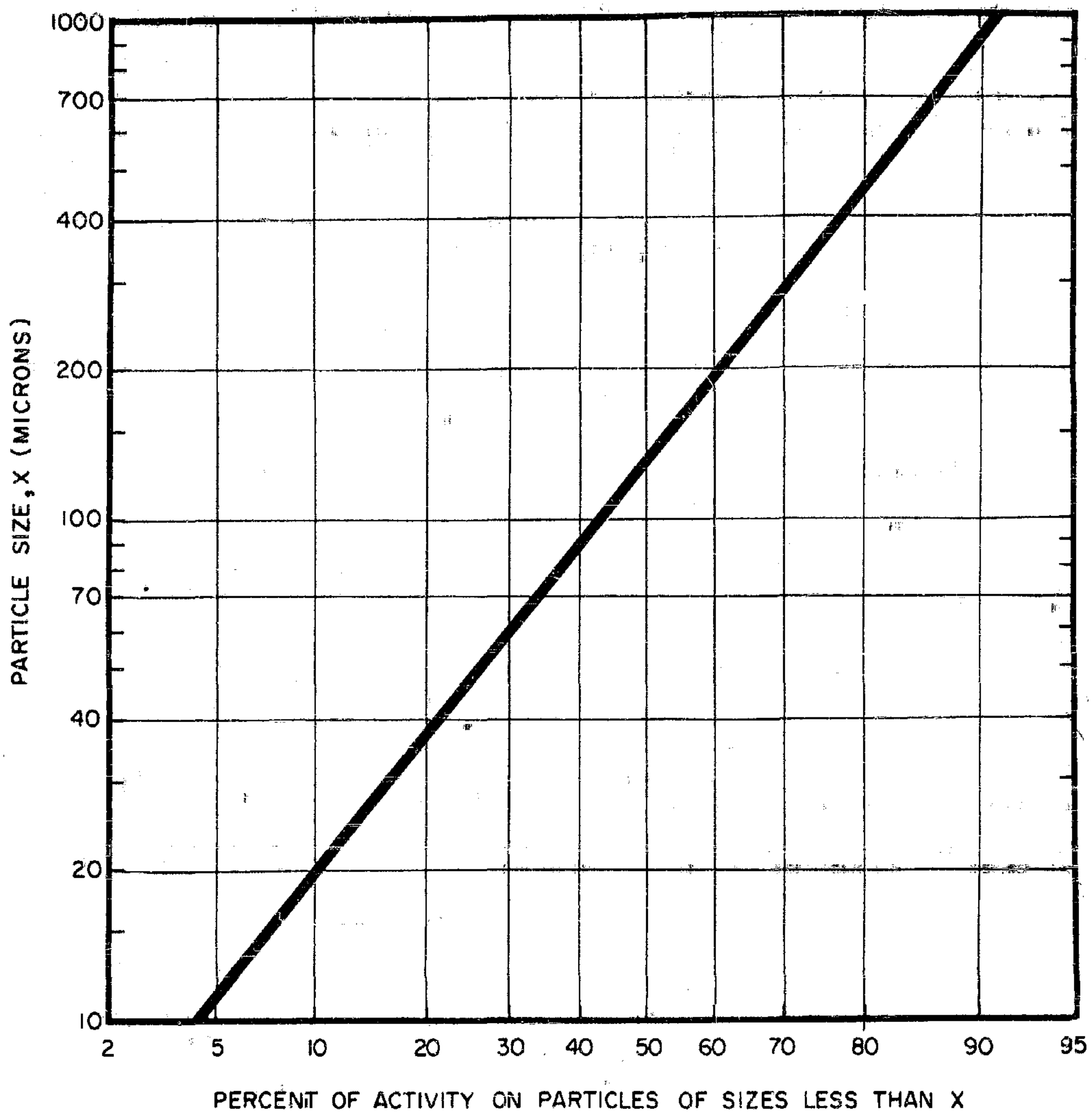


FIGURE 4.1

AMOUNT OF ACTIVITY ASSOCIATED
WITH THE DIFFERENT PARTICLE SIZES

Assumption No. 3 The radioactivity per unit volume decreases with increasing altitude in proportion to the decrease in air density which is given by the relation:

$$\rho\ (h) = \rho_o e^{-h/\ell} \qquad (4.1)$$

where

ρ (h) = air density at altitude, h.

ρ_o = air density at sea level (h = o) = 1.225×10^{-3} gm/cm^3

h = height above sea level

ℓ = constant = 8×10^5 cm.

Air density and pressure decrease by a factor of about three or four between the bottom and top of the cloud in a high-yield weapon. External pressure must balance the pressure within the cloud at the time of stabilization. Then, since the temperature is not likely to be quite different than that of the surrounding air, the universal gas law determines that the density within the cloud must also be the same as the surrounding air. The mass of the cloud therefore is assumed to be distributed in the same way as the surrounding atmosphere.

Assumption No. 4 The particles have the shape of irregular spheres.

This assumption is at present being investigated as part of a program involving the further development of possible operational fallout models.[4] However, there is insufficient evidence at this time to question either the assumption or to test the degree of sensitivity of the model to an assumed particle shape.

Assumption No. 5 In any horizontal cross-section of the cloud, the activity per unit area is constant.

(4) Private communication with R. R. Read at Project Civil, University of California Experiment Station, Richmond, California.

4.2.1.2 Assumptions Made to Simplify Calculations

In addition to the physical assumptions made, several additional assumptions or conditions were assumed to exist in order to simplify the calculations which otherwise would become unmanageable for a hand-computation model. These conditions are as follows:

Assumption No. 1 — The horizontal wind pattern is the same in time and position as that which exists over ground zero at the time of burst.

The wind field that influences the displacement of radioactive particles is, in reality, a continuous one in space and time and may be quite different at some point downwind (up to several hundred miles) from that at ground zero; however, for planning purposes this assumption does not appear to be unrealistic, particularly where the levels are likely to be highest — within 100 miles of ground zero.

Assumption No. 2 — There are no vertical wind currents.

Updrafts commonly exist under certain types of cloud formations, over open fields, on the windward side of hills, over cities, and other areas where heat is generated; whereas downdrafts frequently exist over wooded areas, bodies of water, and on the leeward side of hills. These drafts could probably make a big difference in the amount of fallout landing in any small localized area, but it would be very difficult, if not impossible, to try to include such localized and highly variable effects into any fallout model.

Assumption No. 3 — The cloud has the shape of an inverted truncated cone at the time of stabilization.

This is the regular geometrical shape that seems to satisfactorily describe the now-familiar mushroom cloud.

Assumption No. 4. Particles within the stem of the cloud do not contribute significantly to the total fallout.

Perhaps as much as 10% of the total activity resides in the stem[5] which consists of the heaviest particles dug out of the ground. Because of their larger size and lower altitude, these particles will land much closer to ground zero, and hence add to the levels only at close-in distances where blast damage and other immediate effects are more severe.

To help in simplifying the picture still further, it was found that the particle fall rates were sufficiently high so that sidewise diffusion could be neglected; hence the horizontal displacement rate of the particles is a function only of the wind vector at any particular elevation.

4.2.1.3 Particle Fall Times

Table 4.1 lists the actual particle fall times for particle sizes from 10 to 2000 microns, and for altitudes from 10,000 to 120,000 feet. In order to examine the relative fall times for the different size particles, their times of fall were calculated relative to that for 100 micron particles and the results tabulated in Table 4.2. From this table it is immediately obvious that the ratio of the fall times of any size particle to that for the 100 micron size is quite insensitive to the originating altitude. Thus, the assumption was made that the fall times of all the different particle sizes have ratios that are, for practical purposes, independent of their originating altitude. This allows for tremendous simplification in the model, since we need to compute only the displacement from ground zero of the 100 micron particles (this size is taken solely for convenience), and the displacement for all the others can be found by the simple multiplying factors shown on the bottom line of Table 4.2.

4.2.1.4 Particle Displacements

The horizontal displacement of a 100 micron particle in each layer of, say, 5,000 feet elevation is the product of the time spent in the layer and the wind

(5) "Close-In Fallout", The Rand Corp., Report No. 309, September 30, 1957.

TABLE 4.1

PARTICLE FALL TIMES FROM DIFFERENT ALTITUDES

Particle diameter (in microns)

Altitude (thousands of feet)	10	20	30	50	70	100	150	200	300	500	1000	2000
					Time to fall to ground (in hours)							
10	157	39	17.4	6.05	4.05	2.24	1.20	0.84	0.50	0.30	0.170	0.094
20	306	75	33.9	11.85	7.77	4.39	2.31	1.59	0.95	0.57	0.319	0.184
30	445	109	49.4	17.28	11.05	6.35	3.30	2.26	1.35	0.80	0.446	0.261
40	576	141	64.2	22.53	14.40	8.15	4.20	2.86	1.70	1.00	0.553	0.325
50	701	173	78.5	27.67	16.76	9.80	5.02	3.40	2.01	1.17	0.645	0.377
60	821	204	92.8	32.71	19.40	11.30	5.79	3.89	2.28	1.32	0.729	0.420
70	936	234	106.7	37.75	22.02	12.76	6.51	4.34	2.53	1.45	0.792	0.455
80	1045	264	120.2	42.68	24.64	14.15	7.21	4.76	2.76	1.56	0.848	0.484
90	1145	292	133.3	47.46	27.20	15.44	7.90	5.17	2.97	1.66	0.893	0.508
100	1234	318	145.6	52.06	29.64	16.67	8.56	5.56	3.17	1.75	0.932	0.528
110	1307	341	156.8	56.43	31.98	17.85	9.18	5.93	3.35	1.83	0.966	0.545
120	1365	361	166.8	60.52	34.21	18.98	10.77	6.26	3.52	1.91	0.996	0.559

TABLE 4.2

PARTICLE FALL TIMES FROM DIFFERENT ALTITUDES NORMALIZED TO THAT FOR 100 MICRON PARTICLES

Altitude (thousands of feet)	Particle diameter (in microns) 10	20	30	50	70	100	150	200	300	500	1000	2000
						Relative fall time						
10	70.2	17.4	7.78	2.69	1.81	1	.535	.374	.224	.134	.0759	.0420
20	69.7	17.1	7.72	2.71	1.77	1	.526	.363	.216	.130	.0727	.0419
30	70.1	17.1	7.77	2.71	1.74	1	.520	.356	.212	.126	.0702	.0410
40	70.7	17.2	7.88	2.78	1.72	1	.516	.352	.209	.123	.0679	.0398
50	71.4	17.6	8.00	2.82	1.71	1	.513	.347	.205	.119	.0658	.0385
60	72.7	18.0	8.21	2.90	1.72	1	.512	.344	.203	.117	.0646	.0371
70	73.4	18.3	8.38	2.95	1.73	1	.511	.340	.199	.114	.0622	.0358
80	73.9	18.6	8.48	3.01	1.74	1	.509	.336	.195	.110	.0599	.0341
90	74.1	18.8	8.63	3.08	1.76	1	.510	.334	.192	.107	.0577	.0329
100	74.0	19.0	8.74	3.11	1.78	1	.512	.333	.190	.105	.0559	.0317
110	73.3	19.2	8.78	3.17	1.79	1	.514	.332	.188	.102	.0541	.0305
120	71.9	18.9	8.79	3.19	1.80	1	.568	.330	.186	.100	.0524	.0294
Average for altitudes between 40,000 and 120,000 feet	72.8	18.4	8.40	3.00	1.70	1	.518	.340	.196	.111	.0600	.0345

vector that represents that atmospheric layer. The total displacement from ground zero is the vector sum of all the individual displacements. In symbols,

$$D = \sum_{i=1}^{h_o} V(\Delta h_i)\, \Delta t_{h_i} \qquad (4.2)$$

where D is displacement from ground zero, V the wind vector, Δh_i the wind layer at elevation h_i, h_o the originating altitude, and Δt_{h_i} the time spent in layer h_i.

The position of all particles can now be found by the relation:

$$D(x) = D(100)\, T(x/100) \qquad (4.3)$$

where D (x) = Displacement of particles with diameter x

D (100) = Displacement of 100 micron particles

T (x/100) = Ratio of fall time for particles with diameter x to that for 100 micron particles

Values of T (x/100) are the ones given on the bottom line of Table 4.2, while the 100 micron displacement, D (100), is shown on Figure 4.2 as a function of altitude for a 1 mph windspeed.

With this simplification in the computational procedure, the model next introduces a method for determining the deposition of particles. At the time of stabilization, the cloud is assumed to have the approximate shape of an inverted truncated cone, with distribution of radioactivity within the cloud accounted for above. The dimensions of the cloud at the time of stabilization have been observed in past weapon tests and are recorded in Figure 4.3. (6)

The truncated cone is divided into circular disks of varying thickness so as to give equal activity. The radius of each disk is that of the cloud at the mean height of the disk. Instead of following particles to the ground the model plots the position of circular disks on the ground. The entire disk is assumed to remain intact throughout its journey from the cloud to the ground. The position of all of these disks, therefore, depends on the final positions of the centers of the disks. Since there is a wide range of particle sizes, each contributing different amounts of radioactivity, the truncated cone is subdivided into disks containing only one particle size (the 100 micron particle) from each altitude.

(6) See Reference (1), pp. 282-283

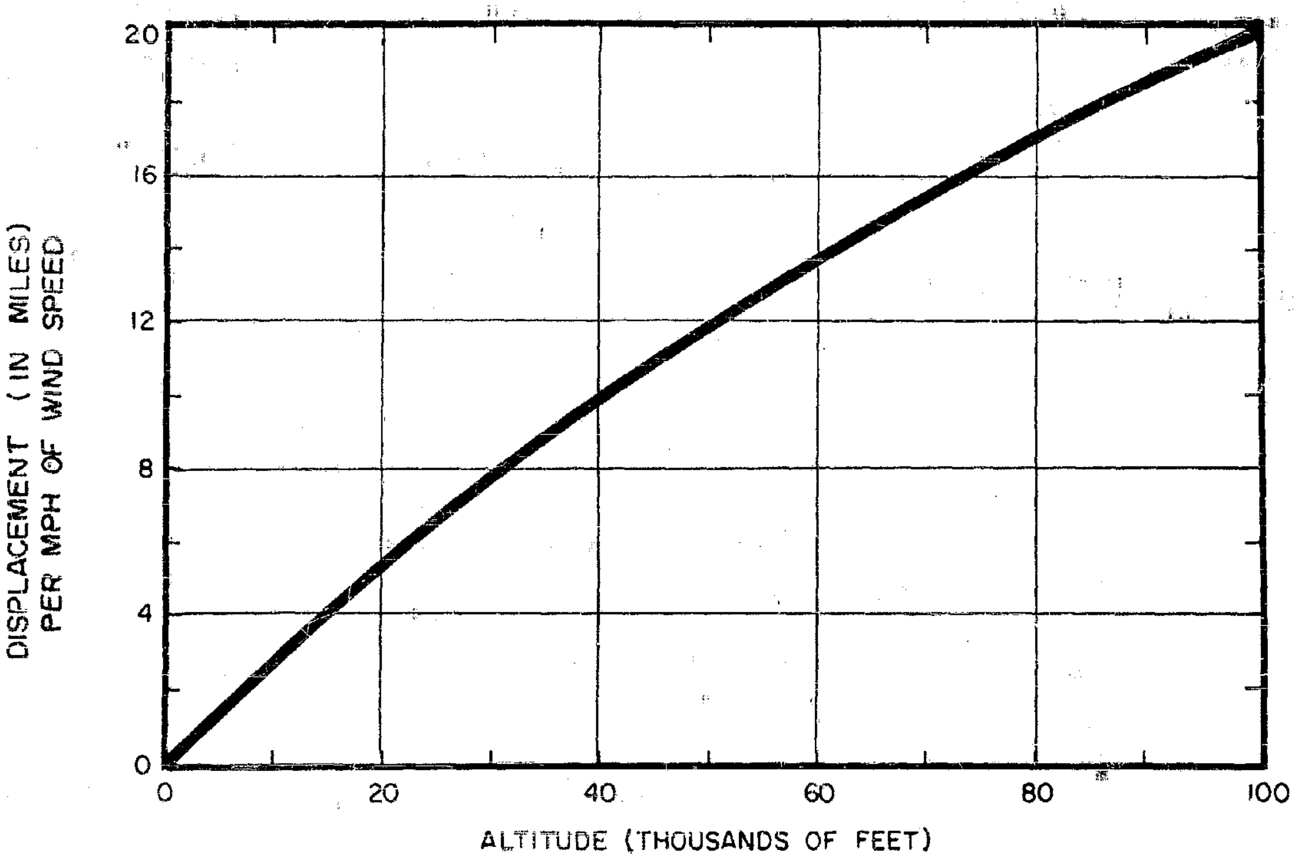


FIGURE 4.2

DISPLACEMENT OF 100 MICRON
PARTICLE VS. ORIGINATING ALTITUDE

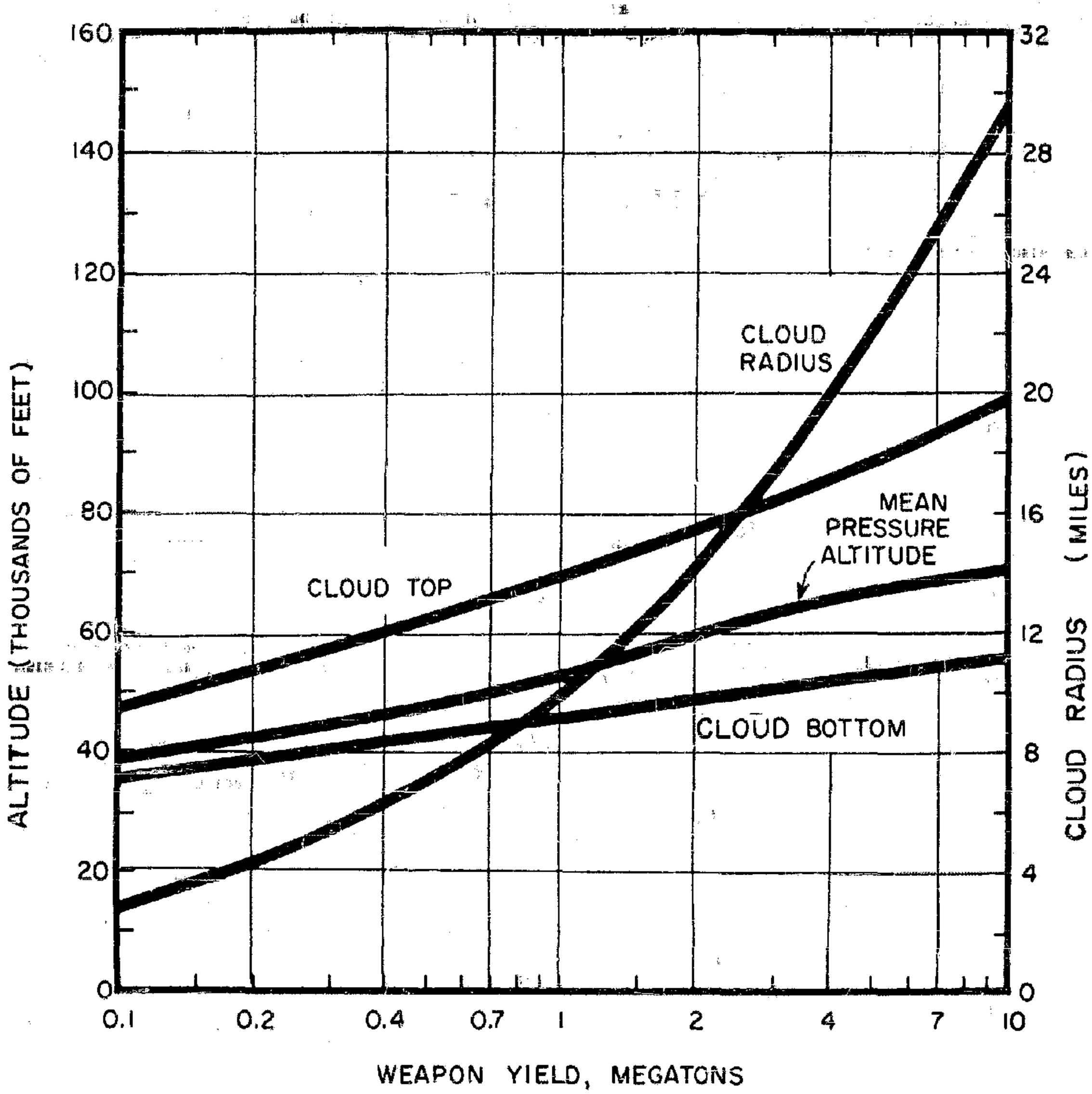


FIGURE 4.3

CLOUD DIMENSIONS AND MEAN PRESSURE ALTITUDE

VS.

WEAPON YIELD

In this way, the knowledge about activity distribution and fall rates for each particle size can be taken up in turn. The total number of disks of each particle size from all altitudes is then calculated, and the total activity at any specific point on the ground is the sum of the activity contributions from all disks falling at that point. For a given wind condition the disks will fall along a radial line from ground zero to the downwind direction, the disks containing the larger particles naturally falling closer to ground zero. It has been shown above that, for final calculations, it is necessary to know only the position of the 100 micron particle disks. Displacement ratios of disks of other particle sizes can be calculated as shown above, and these disks plotted on the ground.

4.2.1.5 Determining Amount of Activity at any Point on the Ground

Referring to Figure 4.4, consider a point P on the ground, and a circle C of radius r drawn equal to the radius of the particular cloud radius from altitude h. The near intersection A of C with the radial line and the far intersection B of C with the radial line enclose the range of particle sizes from altitude h that contributes to the activity at P. Let $F(\mu)$ define the fraction of total radioactivity associated with a particle size of μ or smaller. If μ_s is the smallest particle size contributing to point P, and μ_b the largest, then $\Delta F = F(\mu_b) - F(\mu_s)$ is the fraction of total disk activity from height h that contributes to P when the diameters of the particles are such that $\mu_s \leq \mu \leq \mu_b$.

From each altitude, the values of ΔF can be computed, and the total activity at P derived by summing ΔF over all altitude slabs and multiplying by the activity per slab. The larger particles from a given altitude make a greater contribution since they contain a greater fraction of the activity to start with, they arrive sooner and hence have more time to contribute, and because the activity decays quite rapidly with time (at the assumed rate of $t^{-1.2}$). By marking off fall times into a number of suitable reference times, $t_1, t_2, \ldots t_n$, one finds the amount of activity that has arrived up to t_i. The activity that arrives in the interval t_i to t_{i+1} is determined next, and, finally, by using a conversion factor, the total 2-day dose can be calculated from the relation:

$$\text{2-day dose} = C \, \Delta I_i \int_{t_i}^{48} t^{-1.2} \, dt \qquad (4.4)$$

where C is the conversion factor, and ΔI_i is the incremental amount of activity per unit area arriving in the i^{th} time interval.

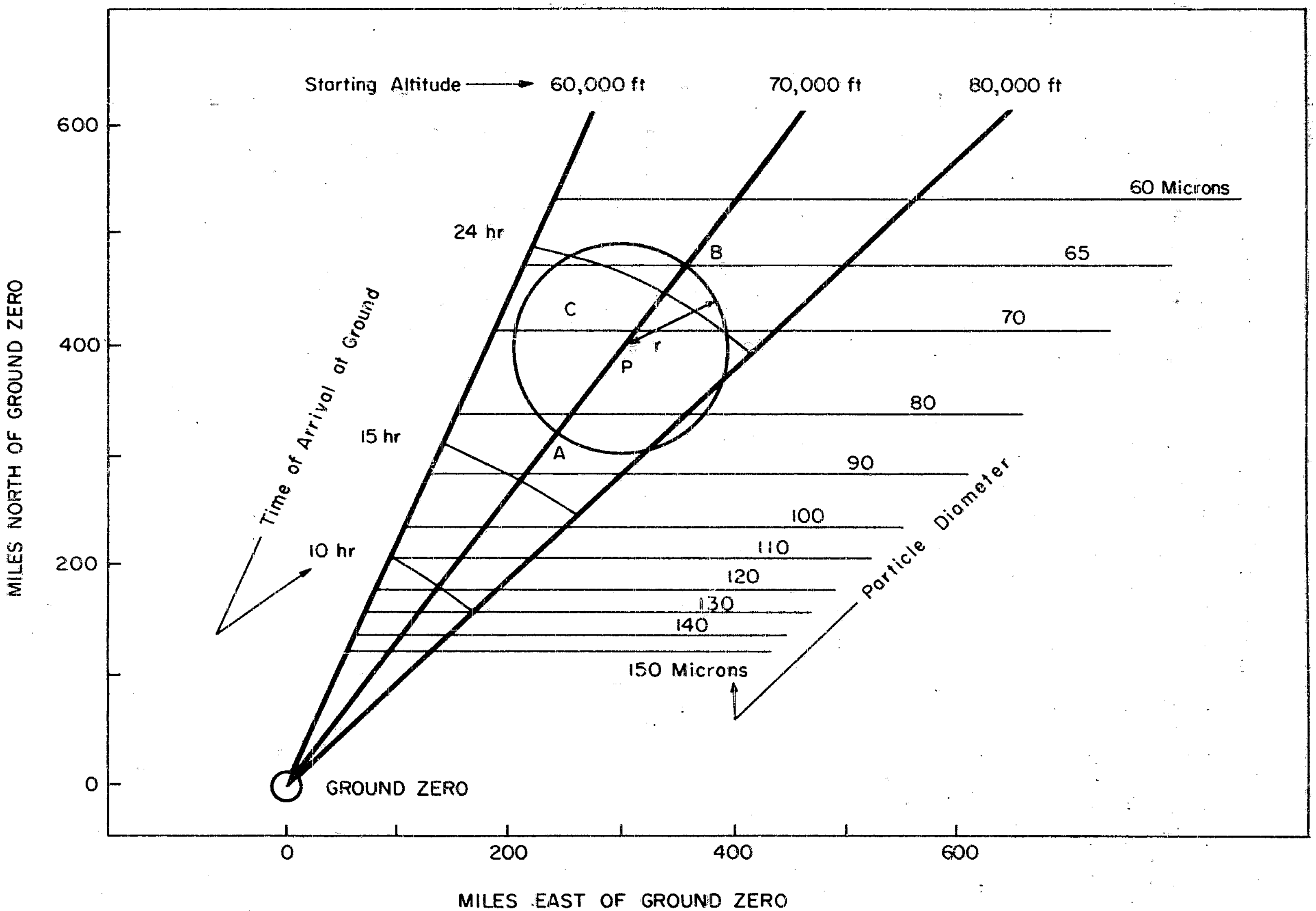


FIGURE 4.4 POSITION ON GROUND OF A TYPICAL DISK

In order to evaluate the conversion factor, C, three final quantities must be specified. The first of these is called the fission efficiency factor and refers to the fraction of the bomb's total energy that is derived from the fissionable material. This factor is taken to be 0.67 for the megaton size weapons, with the remaining one-third of the energy assumed to come from the fusion process. This estimate is about midway between the figure of >0.80 in the book "Nuclear Explosions and their Effects" put out by the Indian government[7] and the value 0.50 used in the OCDM-NDAC fallout model.[8] The RAND fallout model also uses a value of 0.67 for this quantity.

The second quantity required before "C" can be determined is the ground roughness factor. This is a reduction factor which takes into account the fact that the radiation intensity will be lower over average "flat" terrain than that calculated for a theoretically infinite plane. Experiments carried out by the Chemical Corps several years ago indicated a ground roughness factor of 0.70 for the Salt Lake salt flats in Utah, and the factor should realistically be lower for almost any other reasonably "flat" terrain. A value of 0.55 was arbitrarily assumed for this model. By contrast, the RAND model does not specifically take this reduction effect into account (i.e., uses a value of 1.00).

The final quantity required is the factor relating kilotons of fission energy per unit area to the dose rate at a specified time (such as one hour) after burst and point (such as 3 feet) above an ideal infinite contaminated plane. Various authorities have used values anywhere from 1250 r/hr (at one hour after burst) per KT/sq. mile to 3500 r/hr per KT/sq. mile.* The value assumed for this model was taken to be 1580 r/hr, per KT/sq. mile.

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(7) Nuclear Explosions and their Effects, Publications Div., Ministry of Information and Broadcasting, Government of India, October 1958, pg. 26.

(8) Lapp, Ralph E., "What is the Price of Nuclear War?", Bulletin of the Atomic Scientists, October 1959.

* See Chapter 6, Section 6.3.2 for a detailed discussion of this conversion factor.

4.2.2 Two-Day Dose Contours

The purpose of this section is to outline a shorthand procedure for drawing two-day dose contours using UF wind data (see Chapter 3, Section 3.1 for a description of the wind parameters used). The method, good over the range of weapon sizes from 1 to 15 megatons, requires only a protractor, ruler, and the several graphs included below. Figure 4.5 identifies pictorially the parameters that are used. The steps are as follows:

1) From Figure 4.3 determine for the particular weapon size, the cloud radius, cloud height and mean pressure altitude.

2) Convert the UF 80,000 foot integrated wind speed to 100 micron fall points by determining the 100 micron particle displacement per mph of wind speed from Figure 4.2 for the mean pressure altitude. Multiply this displacement by the UF wind speed. The product is D (100).

3) Draw a coördinate axes system on the "map" with ground zero as the origin and one of the axes pointing to the north. From the given UF 80,000 foot integrated wind direction, draw the mean wind trajectory (angles are measured in degrees clockwise from north).

4) Determine the 40,000 - 80,000 wind shear by subtracting the 80,000 foot integrated wind direction from the 40,000 foot direction; add 10% to this figure to account for the differences in this calculation from the wind shear as defined in the fallout model (see discussion in Section 3.6).

5) Draw the shear angle in such a way that the mean wind trajectory bisects this angle.

6) From the known maximum cloud radius r_1, compute $r_2 = .4 r_1$, the mean cloud radius.

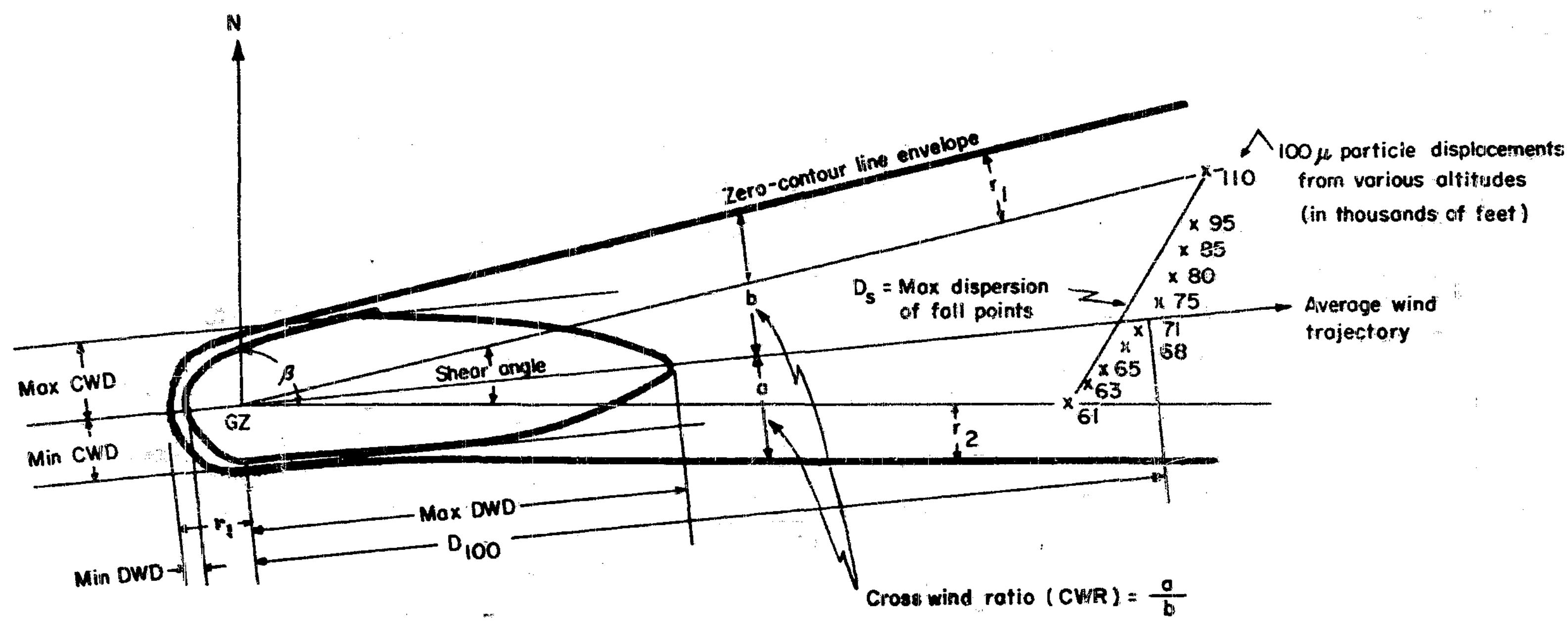


FIGURE 4.5

DESCRIPTION OF CONTOUR PARAMETERS

7) Draw a semi-circle upwind around ground zero with radius equal to r_1.

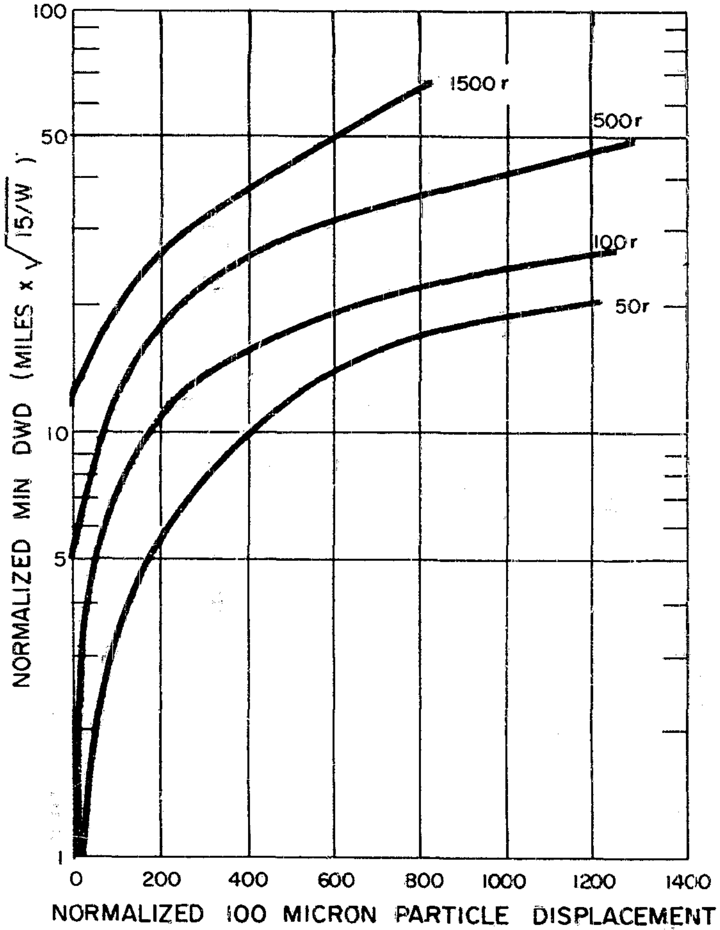
8) Compare the wind directions of the 0-40,000 foot vector with the 0-80,000 foot vector. If the former is greater (smaller), draw a line parallel to that side of the shear angle which creates the larger angle from the north and $r_2(r_1)$ units from this angle side. Draw a line parallel to the other side of the shear angle and $r_1(r_2)$ units from it.

9) Connect the semi-circle drawn in (7) with the two lines drawn in (8). This contour defines the zero contour.

10) Enter Figures 4.6a, 4.6b, and 4.7a with the value $D(100)\sqrt{\frac{15}{W}}$, where W is the weapon size; exit these figures with a scaled value which is multiplied by $\sqrt{\frac{W}{15}}$. Determine maximum downwind displacement (max. DWD), minimum downwind displacement (min. DWD) and total crosswind displacement (CWD) for 50 r, 100 r, 500 r, and 1500 r contours. Enter Figure 4.7b with the crosswind ratio (see Figure 4.5 for definition) to determine the ratio of minimum to total crosswind displacement. From this last step the maximum crosswind displacement (max CWD) and minimum crosswind displacement (min CWD) can be found.

11) Plot these points on the map. From the appropriate category of wind shear (low, moderate, or high) as determined in Chapter 3, Section 3.6), estimate using Figure 4.8, the point downwind where the maximum width occurs. Sketch the general shape of this contour. Plot maximum CWD (minimum CWD) on the same side of the shear angle as $r_1(r_2)$.

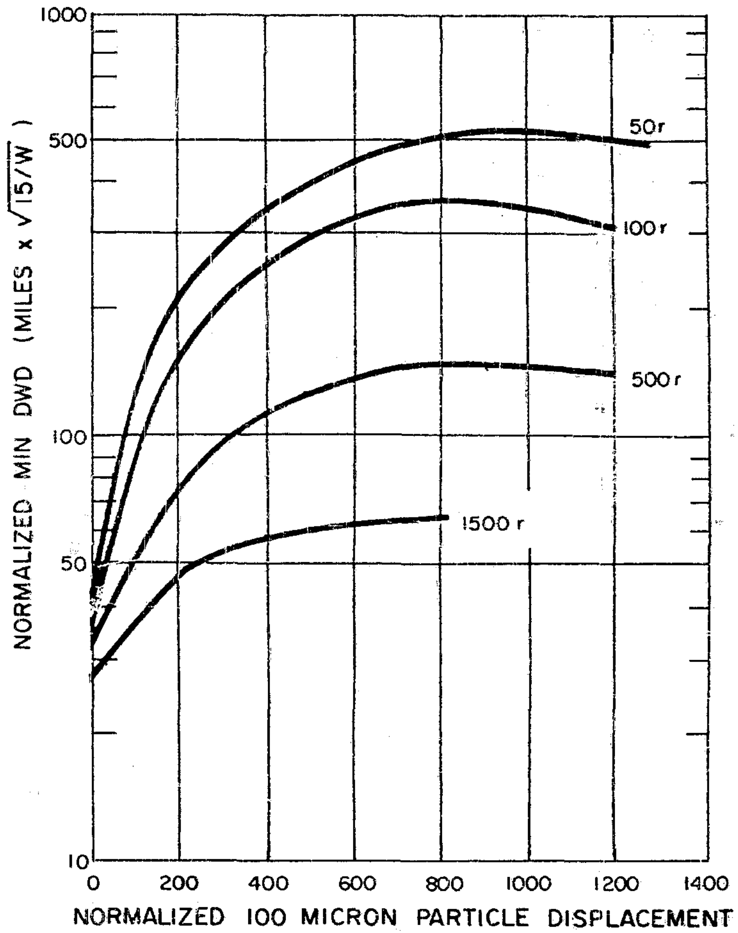
Although the above procedure results in four contours (50 r, 100 r, 500 r, and 1500 r), any number of contours in between these values may be drawn in simply by plotting a given dimension (for instance, maximum downwind displacement) for the known contours vs. the two-day dose, and interpolating between the original contours.



D (MILES x $\sqrt{15/W}$)

FIGURE 4.6a

Minimum Downwind Displacement (DWD)
of 2-Day Dose Contours (W = weapon size in megatons)



D (MILES x $\sqrt{15/W}$)

FIGURE 4.6b

Maximum Downwind Displacement (DWD)
of 2-Day Dose Contours (W = weapon size in megatons)

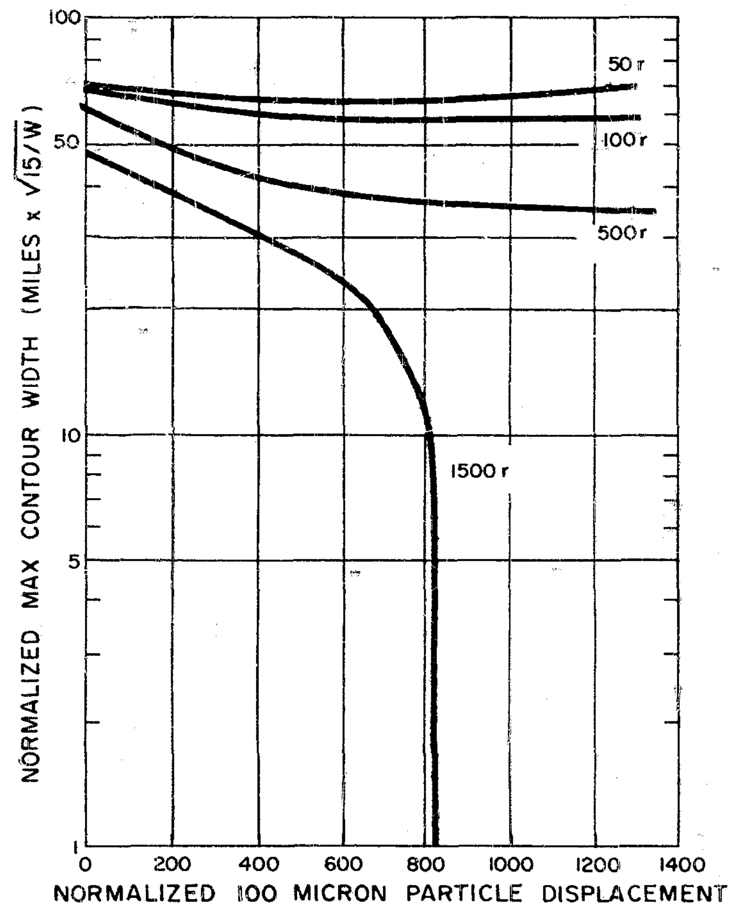


FIGURE 4.7a

Total Crosswind Displacement (CWD) of
2-Day-Dose Contours (W = weapon size in megatons)

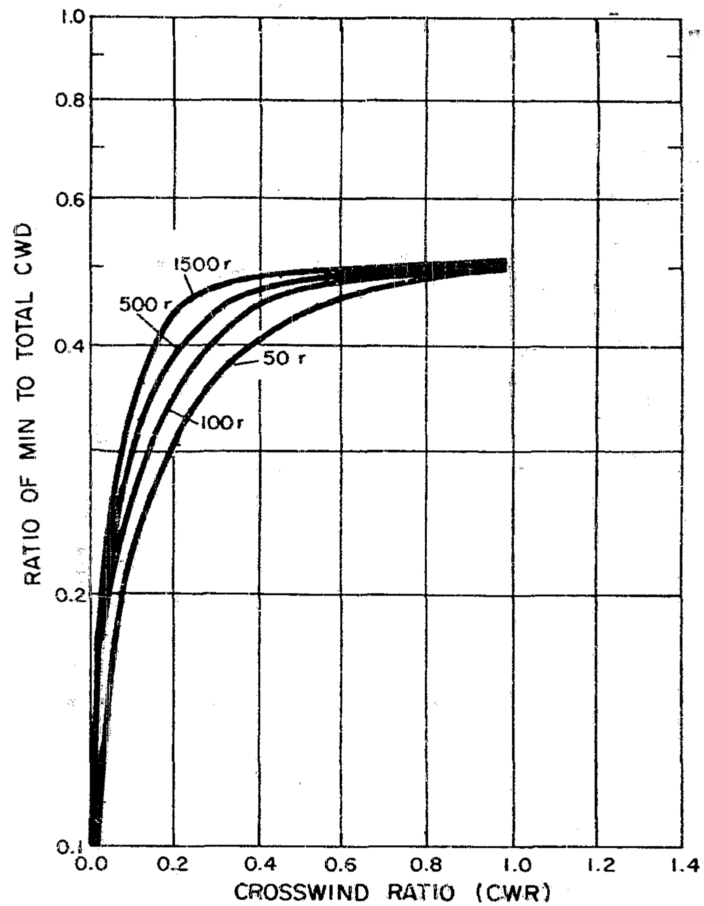


FIGURE 4.7b

Ratio of Minimum to Total Crosswind Displacement
(CWD) for 2-Day Dose Contours

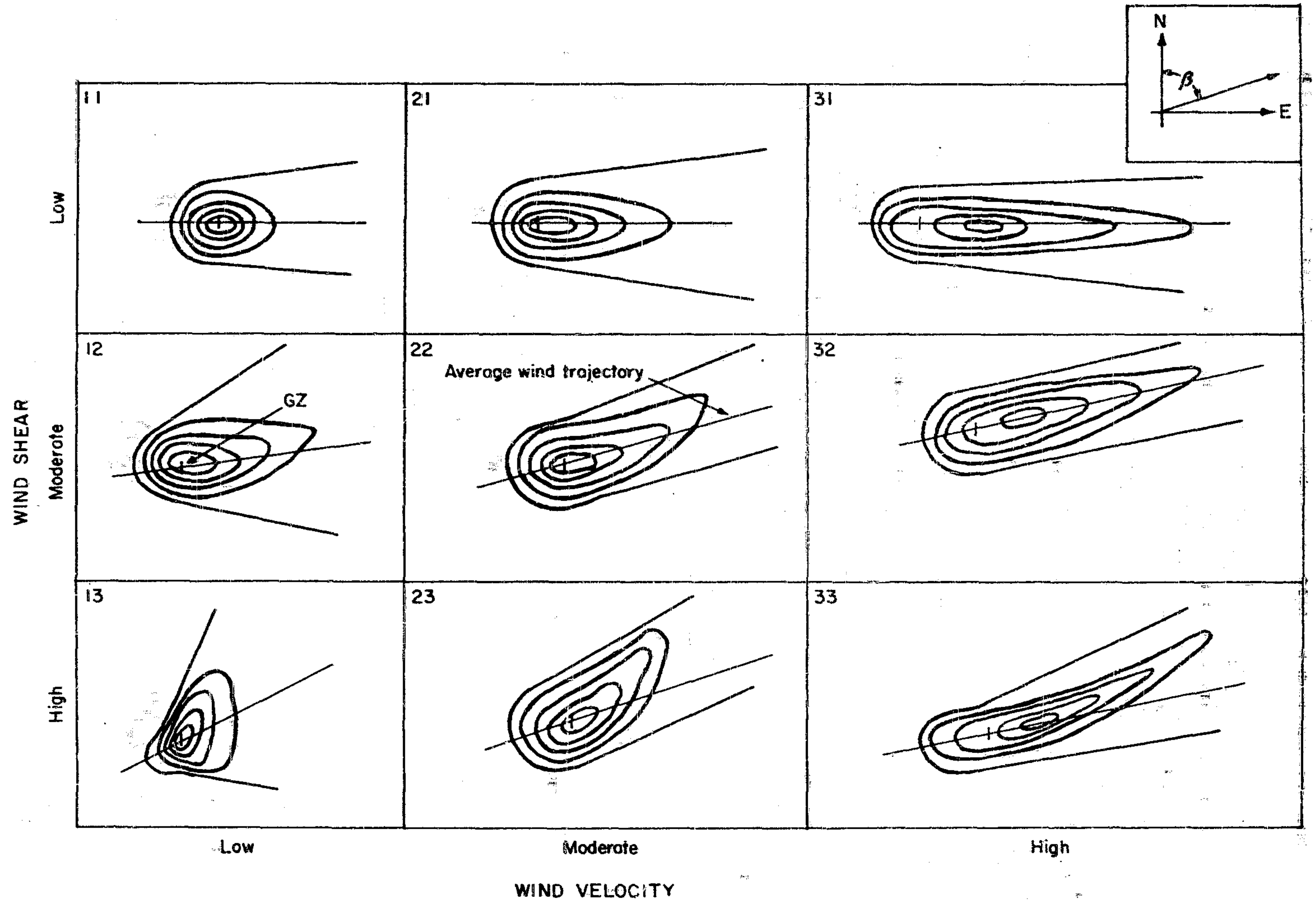


FIGURE 4.8 GENERAL CONTOUR SHAPES VS. WIND VELOCITY AND WIND SHEAR

4.2.3 Example of Shorthand Procedure

To demonstrate the application of the shorthand method described in Section 4.2.2, a single UF wind will be used to calculate two-day dose contours.(9) The 0-80,000 foot integrated wind speed and direction for this example are 23.3 miles per hour (70 mile, 3 hour fall-point) and 110°; the 0-40,000 foot wind direction is 120°. The following steps parallel those outlined in the preceding section.

1) We are assuming a 5-megaton weapon. From Figure 4.3, note that the cloud radius is 22 miles; the cloud height is 90,000 feet; and the mean pressure altitude is 68,000 feet.

2) Enter Figure 4.2 with 68,000 feet to obtain a particle displacement of 15.2 miles for every mile per hour of wind speed. Multiply this by the wind speed (23.3 miles per hour) to obtain D (100) = 355.

3) Draw the coordinate axes and mean wind trajectory as shown in Figure 4.9.

4) The 40-80,000 wind shear is 10°; add 10% to obtain 11°.

5) See Figure 4.9, where the shear angle $\alpha = 11^{\circ}$.

6) $r_2 = .4 r_1 = .4\ (22) = 8.8$ miles.

7) See Figure 4.9, where the outer circle is 22 miles upwind from ground zero.

8) The 0-40,000 wind direction is greater than the 0-80,000 wind direction. Hence a line is drawn parallel to OA and 8.8 miles from it; a line is drawn parallel to OB and 22 miles from it.

9) The two lines drawn in Step 8 and the circle drawn in Step 7 define the zero contour.

10) Enter Figures 4.6 and 4.7 with $355 \sqrt{\frac{15}{W}} = 355 \sqrt{\frac{15}{5}} = 614$ and exit with a scaled value which is multiplied by $\sqrt{\frac{W}{15}} = .577$, to obtain the following dimensions:

(9) The wind used is that recorded at Nantucket, Mass., on May 11, 1959: The UF data was as follows: 41209, 61210, and 81107.

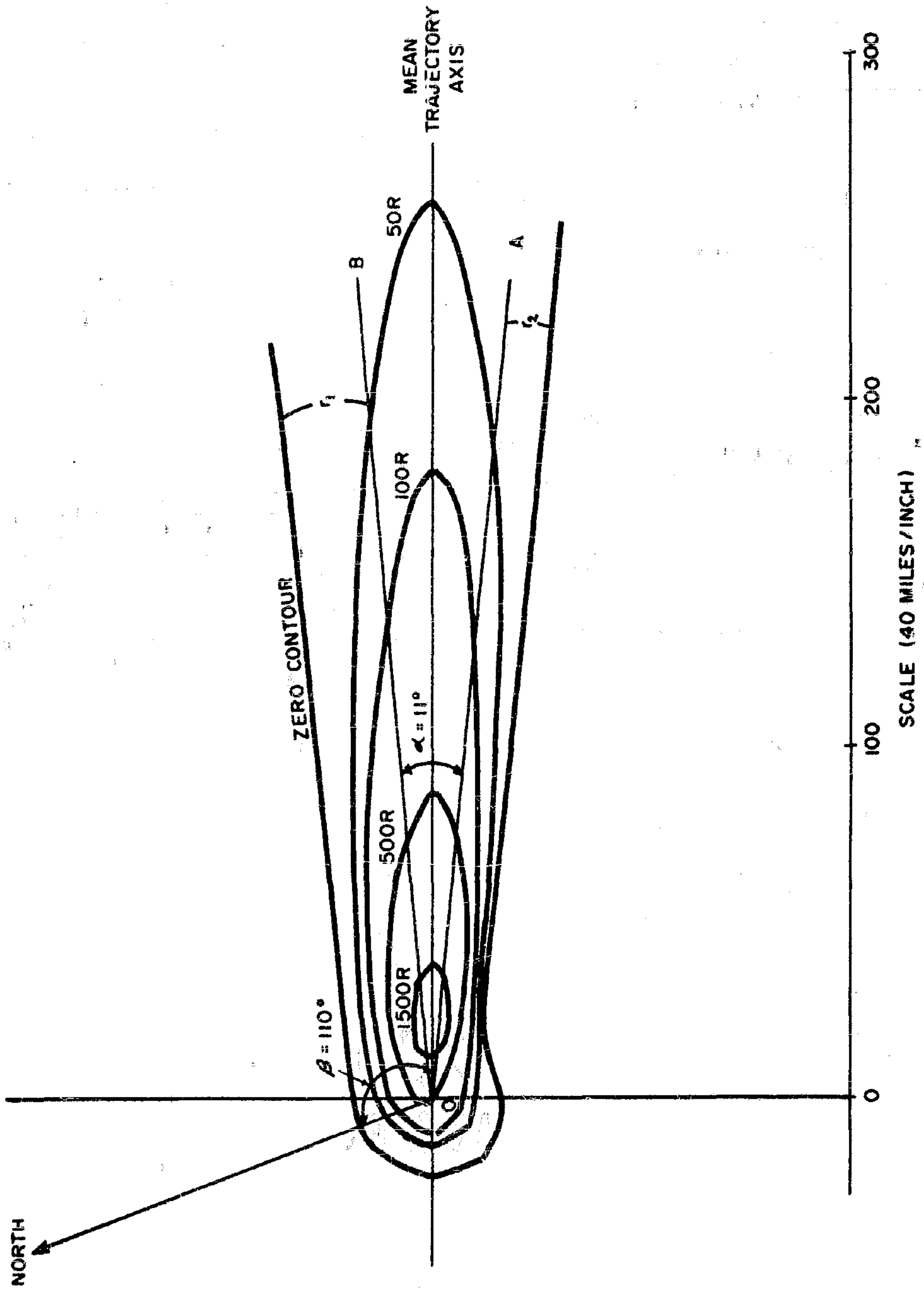


FIGURE 4.9 ESTIMATE OF 2-DAY DOSE CONTOURS FOR 5 MEGATON WEAPON USING UF WIND DATA RECORDED AT NANTUCKET, MASS., ON MAY 11, 1959

2-Day Dose	MAX. DWD	MIN. DWD	MAX. CWD	MIN. CWD
50 R	260	8.7	19	18
100 R	180	11.5	16.5	15.5
500 R	86	19.0	10.5	10
1500 R	35	30.5	6.5	6

11) By using Figure 4.5, which defines the dimensions, and Figure 4.8, which determines the general shape of the contour for this case (low wind shear, moderate velocity), the contours can now be drawn as shown in Figure 4.9.

Additional examples of fallout contours appear in Figure 4.10. These fallout patterns are shown for the winter and summer seasons for each of the two belts that were defined for those seasons (see Chapter 3, Section 3.6). It is clear that the differences in wind speed and shear produce striking contrasts in the contours for Winter Belt I and Summer Belt II.

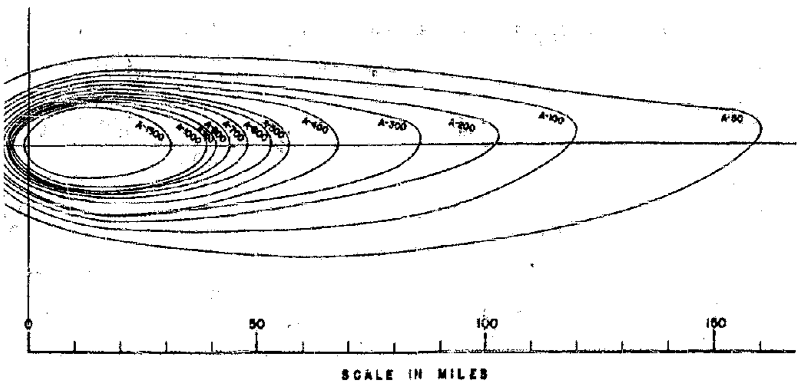
4.3 COMPARISON OF THE TECH/OPS FALLOUT MODEL WITH THE MODEL USED BY OCDM IN RECENT OPERATION ALERTS(10)

Anyone who has had an acquaintance with fallout models knows that they all proceed from a set of physical assumptions — some of which have had little or no experimental verification. Add to this the fact that the various existing fallout models make different uses of wind parameters, and it is not too surprising that wide variances can result in the final contours.(1).

To illustrate how large these differences can be, we have chosen to compare for two specific wind conditions, the contours using the fallout model presented in this chapter with those derived from the fallout model used by OCDM for Operation Alert exercises (often referred to as the AFSWP Scaled Contours). The two wind conditions chosen were Winter Belt I — 46 mph speed, and low shear; and Summer Belt II — 7 mph speed and moderate shear. The Tech/Ops 2-day dose contours for these winds are among those shown in Figure 4.10)

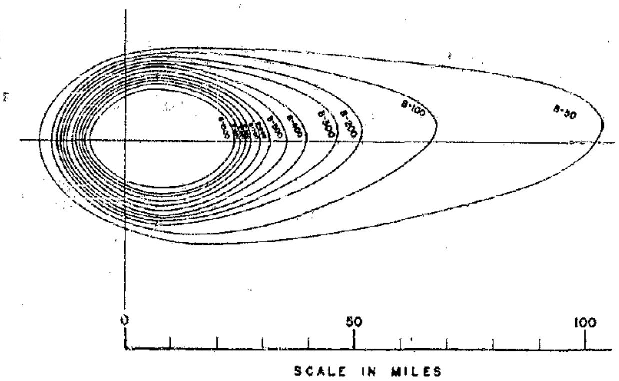
The basic 5-MT dose rate contour data for the AFSWP Scaled Contours was obtained from Table III of reference 7. The two wind speeds chosen were 40 mph and 5 mph. (Since the table in reference 7 gives the contour dimensions only in intervals of 10 mph, the 5 mph values were found by extrapolation.) To make the comparison, these contours were converted to 2-day dose levels by using Table II of reference 7. The results of the comparison are shown in Table 4.3.

(10)See "Standards for Operation Alert", 1958, Attack Phase, May 6-7, 1958.



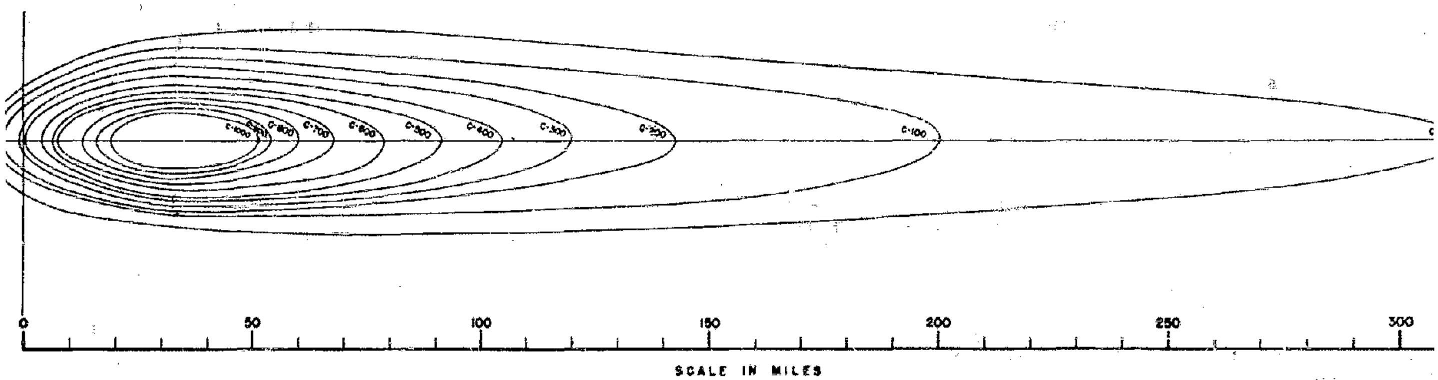
A. SUMMER I, 5 MT, 0-80,000 FT. WINDSPEED 16 MPH. SHEAR 20° (LOW)

ALL VALUES ARE 2 DAY DOSE ROENTGENS



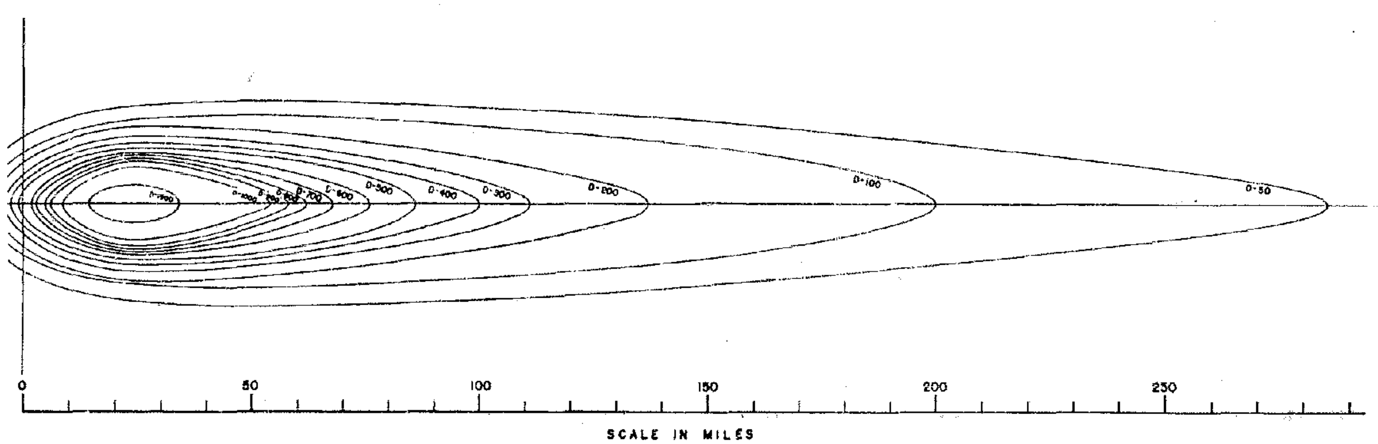
B. SUMMER II, 5 MT, 0-80,000 FT. WINDSPEED 7 MPH SHEAR 48° (MODERATE)

ALL VALUES ARE 2 DAY DOSE ROENTGENS



C. WINTER I, 5 MT, 0-80,000 FT. WINDSPEED 46 MPH. SHEAR 5° (LOW)

ALL VALUES ARE 2 DAY DOSE IN ROENTGENS



D. WINTER II, 5 MT, 0-80,000 FT. WINDSPEED 31 MPH. SHEAR 7° (LOW)

ALL VALUES ARE 2 DAY DOSE IN ROENTGENS

FIGURE 4.10 2-DAY DOSE FALLOUT CONTOURS FOR 5-MT WEAPON FOR MEAN WINTER AND SUMMER WINDS OVER THE U. S.

TABLE 4.3

COMPARISON OF 2-DAY DOSE CONTOUR DIMENSIONS

2-Day Dose (roentgens)	Contour Dimension	Tech/Ops Value (7 mph wind)	AFSWP Scaled Contour Value (5 mph wind)	Tech/Ops Value (46 mph wind)	AFSWP Scaled Contour Value (40 mph wind)
100	Max. DWD	68	115	200	700
	Max. Width	40	90	36	36
500	Max. DWD	35	55	93	395
	Max. Width	32	60	25	20
1000	Max. DWD	25	45	52	306
	Max. Width	23	50	12	17

The most dramatic difference is in the downwind dimension for the high wind speed — the AFSWP Scaled Contours giving a value 3-1/2 times higher for the 100 r contour and six times higher for the 1000 r contour. Since the maximum widths compare rather well for this case, the contour areas differ by the same factor as the downwind dimension. In the case of the light wind, all AFSWP scaled contour dimensions are about a factor of two higher than the corresponding Tech/Ops values, thus making the difference in areas about a factor of four.

Due to unfamiliarity with the detailed assumptions and method of development of the AFSWP patterns no quantitative explanation for these rather large differences can be given. However, the following two factors would tend to make the areas of the AFSWP contours larger than those predicted by the Tech/Ops model:

1) In converting the AFSWP r/hr contours to 2-day dose values, the assumption was made that when fallout arrived (according to the isochrone distance) it all arrived simultaneously. A more realistic assumption might be to assume that the fallout will be coming down over a period equal to the initial arrival time in hours. [8]

2) Although the ground roughness factor (if used in the AFSWP Model) is not known, it may likely be larger than the 0.55 value chosen for the Tech/Ops fallout model.

Further discussion of the differences between the fallout levels over the U. S. predicted by this report and those presented by similar RAND Corp. and OCDM attacks is taken up in Chapter 6 where the patterns developed in this chapter are used to determine the probable fallout threat over the country under two different attack levels and two averaged wind conditions.

CHAPTER 5

CUMULATIVE FALLOUT FROM MULTIPLE WEAPONS USING THE DENSITY ANALOG TECHNIQUE

5.1 INTRODUCTION

The total fallout that might occur at any geographical point after a full-scale nuclear attack will, in many cases of interest, result from the cumulative effect of a number of weapons — perhaps up to 30 or 40 — rather than a single bomb. This cumulative effect is of prime importance near the major target complex areas where the highest fallout levels are most likely to be found.

If one is interested in estimating the fallout levels at only a few specific points due to a proposed multi-bomb attack, the simplest scheme is probably to draw or superimpose the fallout contours for each contributing weapon on a map and manually add up each individual fallout contribution to obtain the total at the specific points in question. In order to study the over-all radiological situation for planning purposes, however, one must be able to see not isolated points but contours of isodose or isointensity covering areas up to and including the Continental United States.

In the previous Tech/Ops Radiological Defense study, an analysis was made of the 2-day dose fallout levels over OCDM Region 1 resulting from nuclear weapons dropped on about 50 targets in or nearby the area.* To carry out the analysis, a 20-mile grid was superimposed over a large map (scale: 8 miles to the inch) of the region, and the 2-day dose from all contributing bombs "itemized" at each of the 500-odd grid points.

Isodose contours showing the 100, 200, 500, 1000 and 3000 roentgen dose levels over the Region were then drawn in by eye to an estimated accuracy of plus or minus ten miles. Even for this relatively small area (compared to the U. S.) and number of targets, the effort required to develop the contours for one attack pattern and wind condition was disappointingly large — 30 to 40 man-hours for the fastest workers and twice that for high school girls and similar inexperienced personnel. Hence, although the technique is inherently capable of any desired level of accuracy depending on the grid size (relative, of course, to the assumed accuracy

* See Chapter 2, Radiological Defense Planning Guide, F. C. Brooks et. al., Report No. TOI 58-26, July 31, 1958.

of the fallout patterns for each weapon), the whole process is just too time-consuming, even for a 20-mile grid spacing, to be attractive except for very limited areas — perhaps the size of one state on the average. In addition, the process is particularly prone to errors because of the large number of separate additions which must be made and categorized. Still another disadvantage is the large map scale required for working purposes.

For these reasons other possible ways of developing 2-day dose contours for hypothetical attacks on the U. S. were explored. Analog Techniques are described in this chapter which appear to have the following significant advantages:

1) The analysis over a large area for a given wind and attack situation takes no more than a few man-hours per hundred weapons.

2) Routine analyses can be carried out by individuals without extensive training or experience.

3) Highly trained individuals can learn to estimate quite precisely the isodose contours from multiple weapons so that after some practice, a several hundred weapon attack can be analyzed in a day.

4) Analyses can be made at smaller and more convenient map scale sizes.

The Photographic Density Analog Technique, described in Section 5.2 was first developed because it can be used for analysis by less skilled technicians, the patterns can be reused for a great many analyses, and it can be used at the small scale of 40 miles to the inch. At this scale no Civil Defense Region is larger than 2-1/2 x 2-1/2 feet, and the continental United States can be represented in a space of 4 x 6 feet.

Since the Photographic Density Analog Technique does require special skills in the preparation of master patterns and takes somewhat longer to make the initial set of patterns, the Layered (Paper) Analog Technique, described in Section 5.3, was developed. This technique requires a somewhat larger scale, 25 miles to the inch, somewhat greater skill in analysis, and a sizeable supply of patterns (because they are short-lived).

Both techniques require the preparation of contour patterns for each combination of weapon size and wind conditions. A person familiar with the fallout model described in Chapter 4 can specify the key coordinates for each combination in an hour.

The maximum error for both techniques is estimated at plus or minus ten miles. The Layer Technique, because of its larger scale, probably has a smaller average error.

5.2 THE PHOTOGRAPHIC DENSITY ANALOG TECHNIQUE

The essential element in this technique is the density analog pattern as shown in Figure 5.1. The density in each area directly corresponds to the minimum fallout within the boundaries of that area. The scale chosen for this work is such that an optical density of 1.0 is equivalent to 500 roentgens. Steps of 0.2 density are, therefore, equal to 100 r. The minimum dose contour of 50 r has a density of 0.1 (film base density). The maximum dose contour used for some patterns is 1500 r. It has a density of 3.0. The analysis of fallout over a given area consists of pattern arrangement and isodensity tracing. The patterns may be arranged by attaching them to a sheet of cellulose acetate, taking care to match ground zeros and wind directions for each weapon (see Figure 5.2).

Density tracing may be accomplished by using the sensing head of a meter-reading densitometer, and following the line of constant optical density for any isodose contour chosen. The approximate path of the sensing head may be chosen by eye. The exact path can easily be found by "hunting". The trace of the path is easily made by using a series of pencil points on a sheet of tracing material that is used to cover the array of patterns on the map outline.

5.2.1 Basic Minimum Equipment and Materials

The patterns are best produced on a moderate contrast, orthochromatic film. Commercial Ortho film, developed in DK-60A to an approximate gamma of 1.0 was used.* The patterns can be made in the quantities needed and to the uniformity required by using a master negative. For one series of patterns, the master negative was made from an assembly of low density negatives, each of

* DK-60A is a standard Eastman Kodak medium contrast developer. Other D-numbers also refer to standard Eastman Kodak developers.

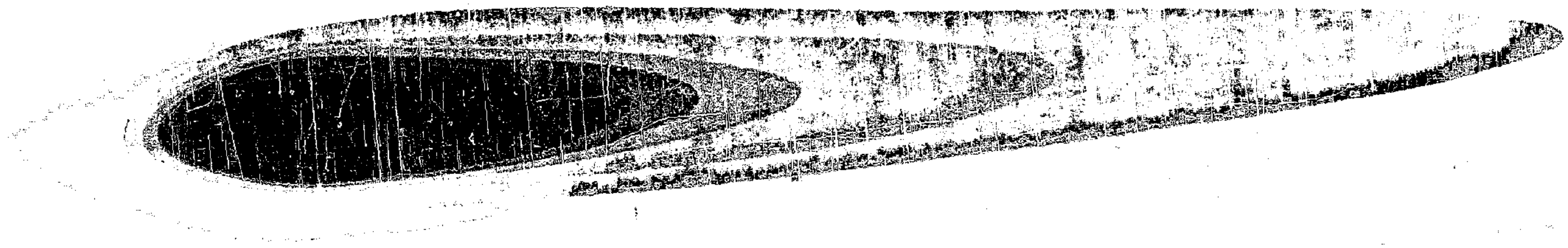


Figure 5.1 Single Photographic Density Analog Pattern

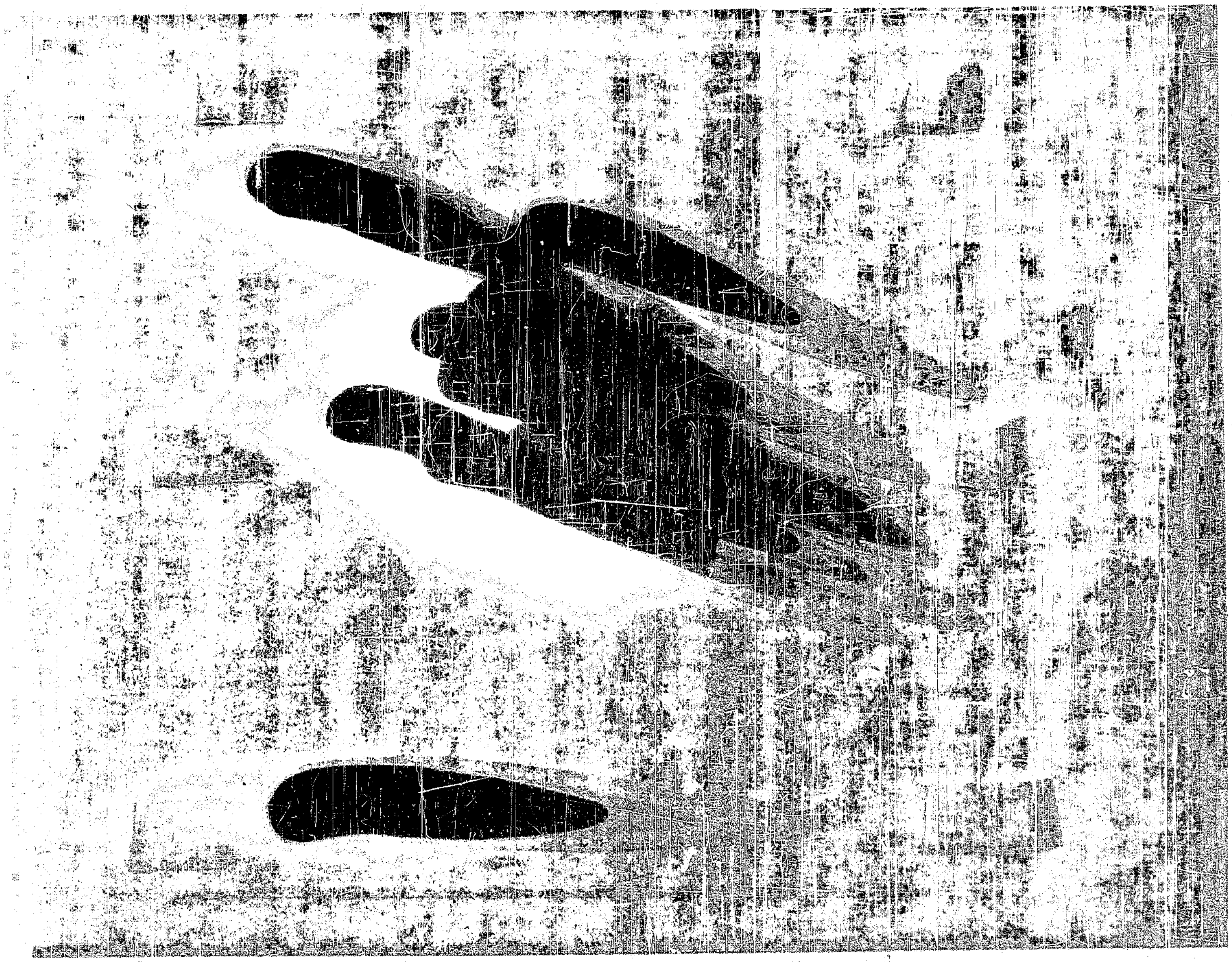


Figure 5.2 Photographic Density Analog Patterns Arranged to Simulate the Fallout From a Nuclear Weapon Attack

which was printed to the outline of a different contour as shown in Figure 5.3. Any high contrast orthochromatic film may be used. For this study, we used Kodalith Ortho developed in dilute D-25 to a gamma of 1.0.

For another series of patterns, the master negative was made by exposing a single piece of medium contrast film (Commercial Ortho) to a series of separate exposures — each one for a different contour. In both techniques, the exposure masks were a series of opaque cutouts, one for every dose contour. The former technique is easier to use, but the latter is faster, once the exposure times for each contour have been determined.

The light source must produce uniform illumination (±5%) over the working area. A diaphrammed 75 watt enlarging bulb was mounted five feet from the 9 x 12 inch working surface. Intensity variations with time were minimized by using a voltage stabilizer. The equipment utilized a variable transformer on the output of the stabilizer to provide smooth control of intensity over a wide range. A voltmeter was placed across the lamp so that the operating voltage could be noted. Exposure times must also be reproducible within very small tolerances. An electric timer was used to control the input to the voltage stabilizer.

Photographic processing can be kept within the prescribed limits by maintaining both constant temperature and a reproducible stylized agitation pattern. The developing tank or tray must be surrounded by constant temperature water at 68 ± 1F, as fed from the usual pressure-compensated thermostatic mixing valve. A regular manual agitating technique by an experienced technician works nicely. Some attempts were made to use nitrogen burst agitation, but they proved to be only moderately successful.

The patterns can be assembled over any reasonably uniform light box. If, however, the light box is to be used for isodensity tracing, it must either be uniform to within ±5% in light intensity or compensations must be made so that the intensity variations do not cause errors in the lines traced.

Isodensity lines may be traced using the sensing head of any meter-reading densitometer. Both the Welch Densichron* and the Ansco-MacBeth Densitometer have more than enough sensitivity and accuracy for this work. The former

* See Appendix A for a description of this instrument

was used. While it is sufficient to use a properly calibrated sensing head over a light box, a somewhat more elegant arrangement can be made by modifying the densitometer light box so that its measuring head is on a long arm over its own internal intensity-regulated source.

The diaphrammed small diameter (3mm) light source of the Densichron light box clearly identifies the point at which density is measured. In this arrangement the assembly of patterns is moved until the meter indicates the density of a preselected isodensity line, the sensing head is raised and then a pencil dot is made over the small area illuminated. If a large area light box is used, it is necessary for the operator to estimate after raising the sensing head where its center had been. For large volume work, a still more elaborate arrangement of a pantagraph-controlled plotting table would be worthwhile constructing.

5.2.2 Construction Techniques and Skills

The key coordinates for significant fallout contours for 5-MT weapons under the four wind conditions illustrated in Figure 4.10 of Chapter 4 are shown in Table 5.1. A draftsman can plot the points, draw the curves and check for internal consistency by examining the gradients at different parts of the pattern. It is advisable to plot at large scale (such as 8 miles to the inch) and then reduce the drawings photographically to the desired scale size.

The next several photographic steps require the talents of a photographic engineer or a highly skilled photographic technician familiar with sensitometric* experimentation. The skills used are perhaps comparable to those of a pattern or tool and die maker, and, in fact, the master negative is just such a master tool. The logical technique for making the master negative seems to be to work backwards, as follows:

1) Expose Commercial Ortho film to a standard photographic step tablet ($\sqrt{2}$ steps preferred). For the particular setup of lamp size and voltage, it may be necessary to run several tests in order to arrive at an exposure time and developing conditions that produce the desired contrast (a gamma equal to 1) and a minimum exposure that makes possible densities equal to 0.2.

* Sensitometry is the photographic procedure used for determining the quantitative response characteristics of a light sensitive material. Appendix B describes the steps involved and the use of characteristic curves.

TABLE 5.1

COORDINATES FOR CONTOURS OF FALLOUT PATTERNS

A. SUMMER BELT I, 5-MT, 0-80,000 FT. WIND SPEED 16 MPH, SHEAR 20° (LOW)

Two-Day Dose (roentgens)	Displacements in Miles from Ground Zero: Downwind Distances, Minimum x	Downwind Distances, Maximum x	Downwind Distances, Maximum y	Crosswind Distances x	Crosswind Distances, Maximum y_1	Crosswind Distances, Maximum y_2
50	-16.1	160	4	17	19	-24
100	-12.3	120	4	17	16	-18
200	-11.2	95	2	17	15	-16.5
300	- 9.5	80	2	17	14	-15.2
400	- 8.4	68	1	17	13	-14.0
500	- 6.9	57	0	17	12	-12.5
600	- 5.7	53	0	17	11.3	-11.3
700	- 5.0	48	0	17	10.7	-10.7
800	- 4.5	44	0	17	10.1	-10.1
900	- 4.0	41	0	17	9.5	- 9.5
1000	- 3.8	39	0	12	9.0	- 9.0
1500	- 0.9	31	0	10	8.0	- 7.0

B. SUMMER BELT II, 5-MT, 0-80,000 FT. WIND SPEED 7 MPH, SHEAR 48° (MODERATE)

Two-Day Dose (roentgens)	Displacements in Miles from Ground Zero: Downwind Distances, Minimum x	Downwind Distances, Maximum x	Downwind Distances, Maximum y	Crosswind Distances x	Crosswind Distances, Maximum y_1	Crosswind Distances, Maximum y_2
50	-18.8	103	4	14	20	-22
100	-16.1	68	4	14	19	-20
200	-15.0	51	2	7	18	-18
300	-14.1	44	2	7	17.2	-17.2
400	-13.4	39	1	7	16.5	-16.5
500	-12.9	35	0	7	16.0	-16.0
600	-11.8	32	0	7	15.0	-15.0
700	-10.9	30	0	7	14.2	-14.0
800	-10.1	28	0	7	13.6	-13.0
900	- 9.5	26	0	7	13.0	-12.0
1000	- 9.0	25	0	7	12.4	-11.4
1500	- 7.8	24	0	7	11.0	-10.0

TABLE 5.1 (Cont'd)

COORDINATES FOR CONTOURS OF FALLOUT PATTERNS

C. WINTER BELT I, 5-MT, 0-80,000 FT. WIND SPEED 46 MPH, SHEAR 5° (LOW)

Two-Day Dose (roentgens)	Downwind Distances: Minimum x	Downwind Distances: Maximum x	Maximum y	Crosswind Distances: x	Maximum y_1	y_2
50	-8.9	314	0	72	24	-20
100	-6.9	200	0	32	20	-16
200	-4.8	143	0	32	18	-15
300	-0.9	120	0	32	16.0	-14.0
400	+0.9	105	0	32	14.0	-12.9
500	4.1	91	0	32	12.0	-12.0
600	6.5	79	0	32	10.5	-10.5
700	7.4	68	0	32	9.3	- 9.3
800	13.0	60	0	32	8.2	- 8.2
900	16.0	54	0	32	7.0	7.0
1000	18.1	51	0	32	6.0	- 6.0

Displacements in Miles from Ground Zero

D. WINTER BELT II, 5-MT, 0-80,000 FT. WIND SPEED 31 MPH, SHEAR 7° (LOW)

Two-Day Dose (roentgens)	Downwind Distances: Minimum x	Downwind Distances: Maximum x	Maximum y	Crosswind Distances: x	Maximum y_1	y_2
50	-10.6	285	0	52	22	-22
100	- 8.4	200	0	52	19	-19
200	- 6.6	137	0	24	16.5	-16.5
300	- 4.4	111	0	24	14.5	-14.5
400	- 2.7	98	0	24	13.0	-13.0
500	- 0.9	86	0	24	12.0	-12.0
600	+ 1.9	76	0	24	11.0	-11.0
700	2.9	68	0	24	10.5	-10.5
800	4.8	62	0	24	9.8	- 9.8
900	6.0	58	0	24	9.2	- 9.2
1000	7.6	54	0	24	8.9	- 8.9
1500	14.4	34	0	24	4.0	- 4.0

Displacements in Miles from Ground Zero

Note: Minimum downwind displacements are from ground zero for ease in plotting (rather than from the upwind zero contour as derived in Chapter 4).

2) Plot the characteristic curve (D log E)* and extract densities of the master negative needed to produce the desired densities for the positive patterns.

3) Establish replenishing procedures for the developer. For this type of numerically precise photographic work, it is necessary to compensate for both developer oxidation as well as developer exhaustion. A suitable technique is to use one gallon of working solution and then replenish two ounces after each 8 x 10 inch sheet of film has been developed. The original developer should soon reach a stabilized condition so that successive sheets are almost identical. The carefully worked and aged solution is then <u>never</u> discarded, because any new stock solution, even if mixed from another can of commercial ingredients out of the same shipping case, will undoubtedly give somewhat different results and take several sheets to settle down to producing consistent results. The replenishment, however, of 2 parts in 128 is small enough so that changes, if any, will be very gradual and further exposure or processing modifications can be made after periodic monitoring of the final densities on the dried patterns. (It may be easier to monitor the system with conventional step tablets.)

4) It should be noted that the inherent errors in the densitometer measuring technique and the processing technique are great enough so that negative densities chosen will not necessarily produce the predicted values. A negative may be deemed acceptable only when a positive pattern printed from it has densities within preliminary tolerance limits. For the previously stated scale of steps of 0.20 D (equivalent to 100 r), such tolerances have been established as follows:

   a. Each positive step ±0.05 D from desired value,
   b. Each difference between adjacent steps 0.20 ± 0.05.

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* Optical density as a function of log exposure, see Appendix B for a more complete description.

The first acceptable trial positive, for the first pattern made, was produced on the fourth attempt. The second, third and fourth trials involved both changes in the master negative as well as in the exposing and processing conditions for making the positive. It is both the negative making stage and the adjustment of both negative and positive exposing and processing by successive approximations that requires the skill and talents of a person experienced in sensitometric methods. Two different methods have been devised for making master negatives. Appendix C describes and compares the two methods.

5) Once a satisfactory negative has been achieved from either master negative technique, it is only necessary to produce the required number of duplicate positive patterns. There will be some variation among these. A reasonable tolerance is ±0.03 D per step. Slight changes in over-all contrast are tolerable so long as no step is further from the average value than 0.03. This repetitive printing and processing can be done satisfactorily by a somewhat less skilled photographic technician, once the procedure has been set up and proved out by the individual making the master negative.

6) At the present state-of-the-art it takes about two days to make a master negative. Thereafter about 20 duplicate positive patterns can be made in a day. For large scale analysis purposes in which 20 or more master negatives (different winds and weapons) and more than 100 positives of each negative are required, it should be possible to reduce substantially the production times. Two persons (a highly-skilled individual with an assistant) working in a well-equipped industrial photographic darkroom should be able to produce at a rate of five negatives and 500 positives per week. For a program of this magnitude "single sheet" master negatives would be used.

5.2.3 Method of Operation

Once a series of patterns has been made for a given selection of weapons and winds, analysis of any hypothetical attack proceeds very quickly as follows:

1) On a map of the desired scale (40 miles to the inch was used) mark every target center along with its weapon size and true north. Allowance must be made for the appreciable changes in the apparent orientation of compass directions caused by flattening the earth's spherical surface to a plane. The distortion of flat maps is quite noticeable in a few hundred miles change in an east-west direction.

2) Mean seasonal wind velocity and directions averaged over a five-year period have been determined at 41 Weather Bureau observing stations around the country. As noted in Chapter 3, the speed and shear characteristics do not change radically with distance, but the direction does. Somewhat arbitrary decisions must be made and recorded for all those target locations that are some distance from fixed Weather Bureau stations of different wind characteristics. Our procedure has been to interpolate wind directions, but to choose the speed characteristic for the location of ground zero. There have been a few cases in which the fallout patterns would appear to overlap in a non-parallel and non-identical wind condition. These have been adjusted to give reasonable local conditions.

3) The fallout patterns can easily be attached to a sheet of transparent material such as cellulose acetate, using high transparency pressure sensitive tape such as Minnesota Mining and Manufacturing No. 810. They can easily be located and oriented if an underlayer of tracing paper is used which contains only registry points, target ground zeros and wind vectors for each target. It is necessary to choose a single master registry point for each map section because tracing paper does change dimension with time and handling.

4) It is convenient to cover the patterns with a second sheet of acetate and then to cover it with a working tracing sheet for plotting isodensity points.

5) By including a single pattern over an otherwise unused area, it is possible to recheck the calibration of the densitometer at any time.

6) Isodensity lines can be drawn readily by inspection for any single pattern or any simple combination of two patterns. For clusters of patterns, it is generally easier to draw most of the low value isodensity lines by inspection.

7) It is sometimes easier to use the densitometer as a null instrument at mid-scale rather than at its calibrated value for zero density equal to zero reading. Any arbitrary point on the meter's scale can be used for a null reference by calibration against the appropriate contour of the reference pattern. A careful person without much technical training can follow an isodensity line and plot pencil points that are accurate to ±0.05 D (±25 r at the density-dose relation used).

8) An experienced person who has worked with the analog technique, often finds it possible to check a relatively few points and fill in the contours by inspection.

9) The densitometer is most useful for plotting isodensity lines in the range of 0.4 to 3.0 D (200 to 1500 r). Lower densities can often be traced by inspection. Higher densities may be beyond the sensitivity of some densitometers when used over commercially available light boxes. These isodensity lines may, however, be generated by inspection of the original contour maps and in any case cover only a very small part of the analysis area. Arrangement of the wide-throat densitometer mentioned above does make it possible to read to 4.0 D (2000 r). In the event of an anlaysis of very great weapon concentration, (more than 100 MT within 100 square miles) it is possible to make patterns for a different relationship of photographic density to roentgens.

10) It is desirable but not essential to have as many patterns as there are weapons in the attack. For an attack covering more than 1000 miles in the direction of the wind or more than 500 miles perpendicular to the typical wind, it would be possible to arrange the patterns for part of the area, trace the isodensity lines through that area and then move the patterns to the adjacent area. Such a procedure reduces the number of patterns to be manufactured but complicates somewhat and slows down the analysis.

11) The plotting of isodensity lines and the transferring of them to a detailed map or to a transparent map overlay might be considered the final phase of the plotting activity. There are, however, advantages in shading differently the areas of different intensity. Analysis by others is facilitated, even if they are experienced personnel, if different colors or different degrees of shading are used for the different ranges of fallout intensity.

12) Various art and photographic materials such as Art-type, Zip-A-Tone, Rolcor Tints and Bourges overlays are commercially available for shading presentations. Care should be taken to select patterns that are significantly and consistently different when examined from distances as close as 5 inches and as far away as 4 feet. The shading effects are produced by varying degrees of coverage of printing inks. It is, therefore, possible to reproduce such charts without screening for half-tone reproduction. Verifax, ditto and multilith processes can be used easily if care is used in the initial selection of patterns. It should be noted, however, that this kind of presentation, particularly when reproduced on commercial printing presses, is limited to three or four steps. The scale used in the illustrations in Chapter 6 was chosen to cover a range of 100 to 10,000 r and is as follows:

100 to 300 r) 300 to 900 r)	white, separated by contour lines
900 to 1500 r) 1500 to 3000 r)	light grey, separated by contour lines
3000 to 6000 r) 6000 to 10,000 r)	dark grey, separated by contour lines
greater than 10,000 r	black

5.2.4 Value As An Operational Research Tool

For every hypothetical attack and wind condition, the gross fallout level in any given area can probably be estimated by an experienced Radef Officer to within a factor of five without any sophisticated analytical aids. The objective of the analog techniques is, with relatively inexpensive equipment, to make possible estimates to within a factor of two. The referenced data, map scales and technique outlined provide for such precision.

Still more precise estimates, perhaps within a factor of $\sqrt[3]{2}$ would be possible if the map scales and analog patterns were appropriately enlarged. A larger scale, however, would increase the cost of making the photographic density patterns and add to the time required for analysis.

The greatest value of the analog technique is the ease with which it is possible to study the effects of different wind directions and ground zeros. A logical extension of this fallout analog technique would be to combine it with population density information such as is available on maps No. 0-290739 of the U. S. Government Printing Office, or No. G3701-E2 of the Library of Congress. From this combined information, one could estimate directly the numbers of people within any specified fallout intensity levels for any specific attack. A still further extension would be to incorporate fallout shelter estimates as a third factor in the analog system.

An extensive program of such studies would require an inventory of density analog patterns covering the expected variety of weapon sizes and wind conditions. The skills necessary for the preparation of master negatives are readily available in many cities, but tend to be expensive. It is, therefore, worthwhile to make new patterns for only those weapon and wind properties that will be used several times for analysis purposes.

While it is possible that the density analog fallout analysis technique could be used profitably for some post-attack studies, its primary value is for planning and training purposes. Some of the studies in which the technique might be particularly useful are as follows:

1) Outlining the areas most likely to need fallout shelter and the various levels of fallout protection required.

2) Outlining the areas that are least likely to have lethal levels of fallout. The location of new essential facilities in such areas may change their safety factor but will then serve further to scatter any eventual attack.

3) Demonstrating to Civil Defense personnel the fallout intensity caused by multiple weapons.

4) Demonstrating the dramatic effects of a change in wind direction by as little as ten degrees, particularly when the analysis point is more than 50 miles downwind from the nearest ground zero.

5) Demonstrating the effect of changes in ground zeros.

The density analog fallout analysis technique may function as a graphic demonstration to local Civil Defense personnel of the coverage and additive effects of radioactive fallout, and thus help them visualize and understand better this physical phenomenon.

5.3 THE LAYERED (PAPER) ANALOG TECHNIQUE

Since the skills and facilities required for producing patterns by the Photographic Density Analog Technique may not be readily available, an alternative system called the Layered Analog Technique was devised and found to be quite satisfactory for making a few fallout analyses. Its precision is largely dependent upon the use of materials that are very uniform in texture.

In this technique the number of layers of material was the analog of the two-day fallout dose. While the material was uniform enough in light scattering and absorption to use a single analog scale, mechanical considerations made it desirable to use separate scales for low and high levels. For low levels (50 to 300 r) one layer was equivalent to 50 roentgens, while for high levels (300 to 1500 r) one layer was equivalent to 300 roentgens. The isolayer contours from multiple weapons were determined for 300, 600, 900 r and higher levels in 300 r increments.

The analysis of fallout over a given area consists of the following five steps: (1) arrangement of low level patterns, (2) tracing of intermediate contours, (3) preparation of composite patterns for the intermediate contours, (4) arrangement of high level patterns (both from single weapons and composites), and (5) tracing of final isolayer contours. As in the Density Analog the patterns are most easily arranged by attaching them to a sheet of clear cellulose acetate, taking care to match ground zeros and wind directions for each weapon as indicated on the map underneath.

Layers are counted and isolayer-isodose lines determined by using a meter-reading densitometer. As noted below there is a unique density value for any number of layers from one to sixty.

The scale of 40 miles to the inch (found suitable for Density Analog work) was too small for the bulk of material encountered in Layer Analog work. A map scale of 25 miles to the inch in combination with the low and high level dose scales was found convenient for handling the many layers of paper from multiple weapon fallout at certain points. At this scale the largest Civil Defense Region was no more than 4 x 4 feet.

5.3.1 Basic Minimum Equipment and Materials

The layers in each pattern were cut of commercially available tracing paper (translucent bond).* The apparent density (from light scattering and absorption) of this material was consistent within ±0.01 density units for single sheets as well as for stacks of various numbers of sheets. Layers were counted with the densitometer by referring to a master precounted scale. While the density difference per layer was not linear (it started at 0.21 D for one layer and dropped to 0.07 D when it reached ten layers) the steps were enough larger than the inhomogeneity to make the error negligible. In a series of 81 tests only one error was made. One operator counted out stacks varying from 9 to 62 layers; a second operator measured the densities, referred to the calibration scale and determined the number of layers.

A variety of other typing and writing papers were examined. All other such materials were found to have single layer variabilities in excess of ±0.05 density units and were, therefore, unusable.

Isolayer lines were traced using the sensing head of the Welch Densichron. Somewhat more care is needed than in the Density Analog work, because the greater thickness of material makes the sensing head more sensitive to stray light. In both techniques it is good practice to calibrate the system with the acetate assembly layers and the tracing paper marking sheet in place. Room lights should be off or very dim.

5.3.2 Construction Techniques and Skills

Sets of contours for each dose level were made by cutting through several sheets of paper at one time. The patterns were assembled and then held together by putting a small amount of cement between each pair of contours. Fast-drying model airplane cement was found suitable. Cementing was done at the ground zeros of the patterns so that density errors could be anticipated and minimized.

It takes one person about a week to make 100 patterns. This includes both low level and high level contours and can include several different wind (or weapon) values. It may be noted that small scale pattern production takes about the same time by either Density or Layer method but that the latter requires less skill, simpler facilities and less set-up time.

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* Source was Clearprint Technical Paper No. 1000H made by Clearprint Paper Co., San Francisco, California. It is believed that any similar tracing paper would be suitable as long as all layers in all patterns in one analysis were made from one make of paper out of the same package.

5.3.3 Method of Operation

The method of operation is the same as for Density Analog work except as follows:

1) Maps with a scale of 25 miles to the inch are used.

2) The paper analog patterns are more fragile than ones made on film. They, therefore, must be handled more carefully and are less amenable to being reused. Similarly they pick up dirt readily and in this way increase the apparent density. It may be a safe rule to use paper patterns no more than 10 times even with the most careful handling. The usage could be for 10 different places in a single attack, 10 different attacks or a combination. A more rugged material such as matte surface Mylar was tried. Patterns made from it will last longer if the patterns are cleaned periodically. It was felt, however, that the added life was insufficient compensation for the greatly increased material cost, cutting difficulties and cementing problems.*

3) The increased size (which was not practical with Photographic Density patterns) and the actual physical bulk seemed to make it easier to determine isolayer lines with only occasional use of the densitometer. Highly skilled people who used the densitometer to make their first few analyses found that they could learn to follow isolayer lines quite precisely. One specific experiment showed that one experienced operator working without a densitometer could produce a contour map almost identical with that produced by another experienced operator using the densitometer in the manner described above. The analysis was of a 15-weapon attack on the military bases and industrial centers around Seattle, Washington.

4) A somewhat more time-consuming technique that does not require a densitometer and is only a little less accurate so long as not too many patterns overlap one another is as follows: Take a single contour of the lowest level and move it from one ground zero to each successive location after sketching the envelope of values at that layer (or dose) level. Higher level contours are then placed, moved and traced successively with care taken to estimate properly the intersection areas of different contour levels.

* Similarly dyed gelatine sheets, such as Wratten filters, were considered but not tried because of material cost.

The accuracy of this system, when carried out by operators experienced in the densitometer technique is estimated at ±1/4 to 1 inch depending upon the nature of fallout pattern intersections and the skill of the analyst. At the scale used of 25 miles to the inch, the maximum error may be ±25 miles.

5.4 A COMPARISON OF THE TWO ANALOG TECHNIQUES

Since the analysis time is approximately the same for both systems the choice between techniques rests on the time and cost of preparing patterns. The paper layer patterns are more practical in quantities of up to 200. The photographic density patterns are easier to make for quantities above 500 if the special skills and facilities are available. By using steel rule dies and semi-skilled labor it might be possible to make large quantities of paper patterns at a price matching that of the photographic density patterns. The volume of work done to date has not warranted study of this latter approach.

For the work reported in Chapter 6 both kinds of patterns were made. The two attacks on the continental United States were analyzed in detail using paper layer analog patterns. Almost all of the analysis was done by one highly skilled operator who used a total of 100 patterns for the four wind conditions (two winter and two summer winds) of the one 5-megaton weapon size. He found that with his densitometer experience, his familiarity with fallout phenomena and the independent tests outlined above, he could take short-cuts at later stages of analysis. It took about two weeks to analyze the first 800 weapon attack, but only four days were needed for the next attack of similar size, and only two days to make a detailed analysis of a 370-weapon attack.

The more rugged nature and more compact size of photographic patterns probably make them more suitable for a standard analysis system. The lower cost for fabrication in small quantities makes the paper layer patterns more suitable for occasional use.

APPENDIX A

THE WELCH DENSICHRON DENSITOMETER

The Welch Densichron (see Figure 5.4) is a photoelectric device commonly used in industrial, commercial and scientific photographic work for measuring the opacity of light transmitting materials. Optical density is defined as follows:

$$D = \log_{10} \frac{I_o}{I_t}$$

Where D is optical density, I_o is intensity of incident illumination, and I_t is intensity of transmitted illumination. Visual response is logarithmic in nature so that steps of equal density appear to the eye to be approximately uniform (the eye is a little less sensitive at high densities than at low densities). The density of a stack of materials is approximately equal to the sum of the individual densities. (Reflection losses, scattering and similar phenomena are usually small and can, therefore, be ignored.) The transmitted light is made to impinge on a photocell. The photocell output, I_t, is read on the meter scale. The commonly available model of the Densichron has a D'Arsonval type meter movement, with shaded pole pieces, that responds approximately in a logarithmic fashion. It is, therefore, possible to calibrate the meter in density units which are approximately evenly spaced (see Figure 5.5).

When used with its own light source, the Densichron will read densities from 0 to 4.0 through the use of a three-position scale switch. The meter scale reads from 0 to 1.0 with divisions of 0.02 (and from 1.0 to 1.5 with divisions of 0.1). The instrument is calibrated against a master photographic film "step tablet". With the correct zero and gain settings, the scale, on the first two range steps (0 to 1.0 and 1.0 to 2.0), is accurate to ±.03. In the highest range it may be in error at some points by as much as ±.05. Precision is ±.02 throughout the 0 to 4.0 span (four orders of magnitude of light intensity) provided that a 30-minute warmup is allowed and that zero and gain calibration is made at least once a day. This instrument with standard accessories sells for approximately $500.00.

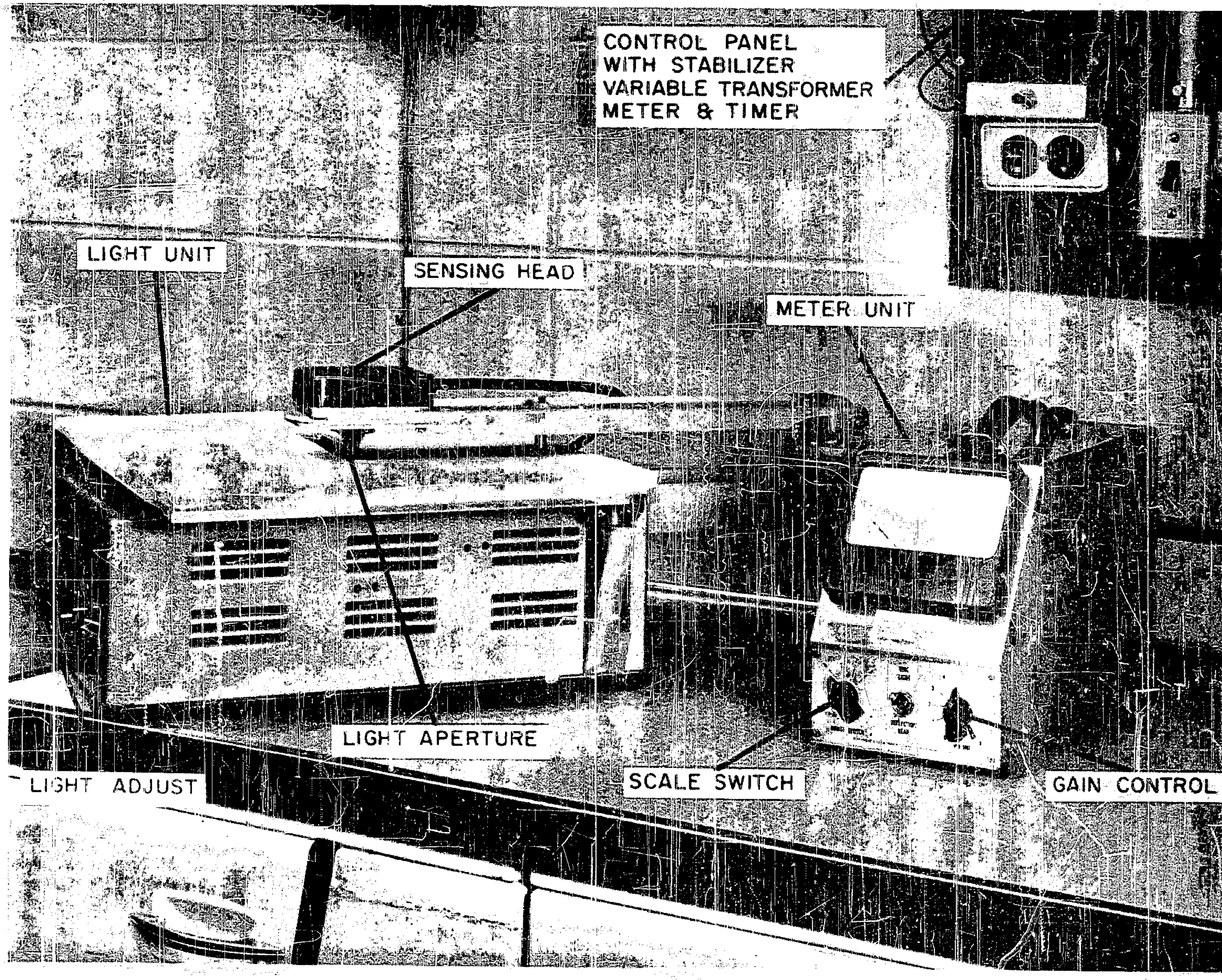


Figure 5.4 Standard Welch Densichron Densitometer With Special Extension Arm for the Sensing Head

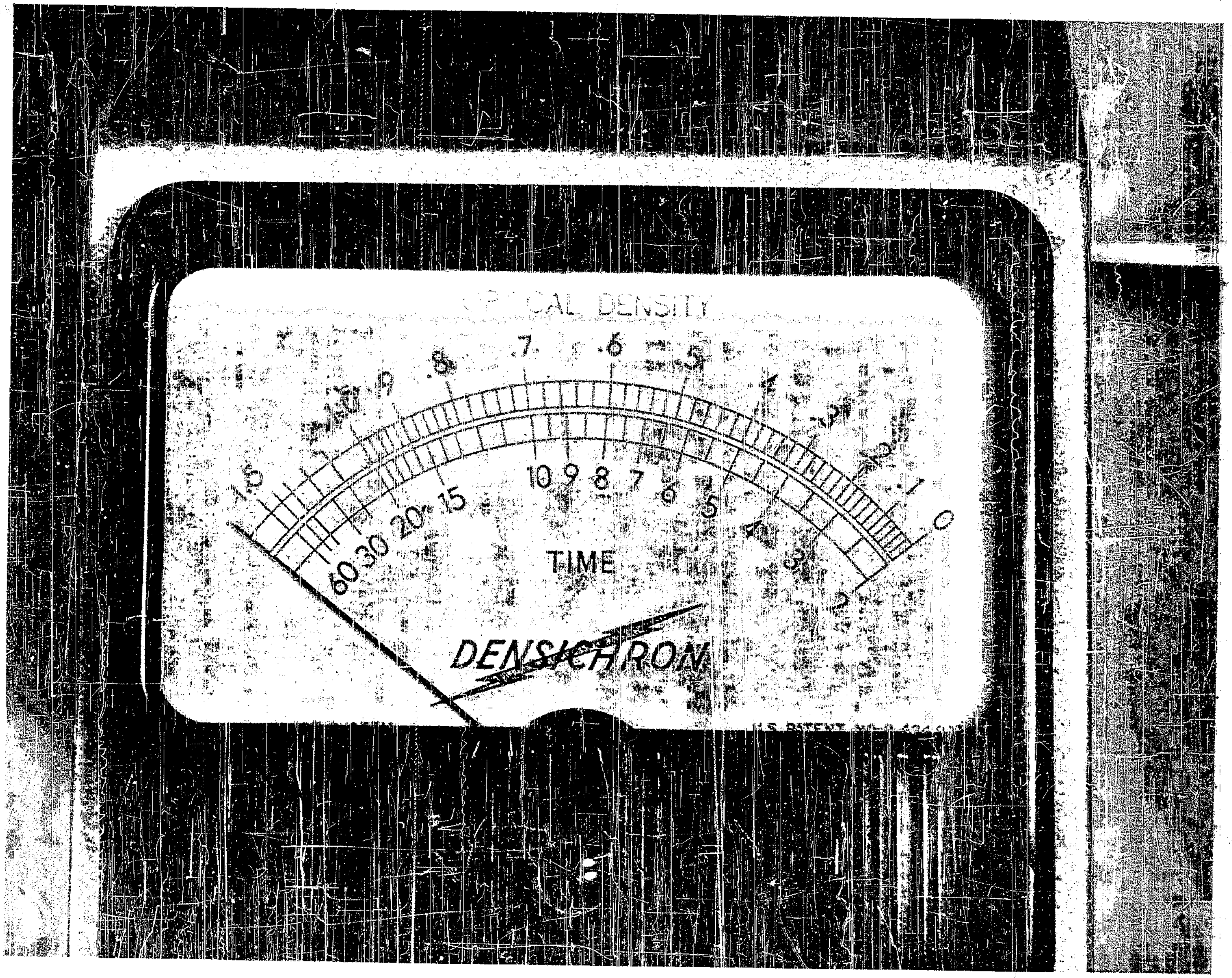


Figure 5.5 Densichron Meter Face Showing the Principal Density Range of 0 to 1.0 As An Approximately Uniformly Spaced Scale

APPENDIX B

SENSITOMETRY

The steps followed in the sensitometric evaluation of a light sensitive material are generally as follows:

1) Expose the material to a carefully calibrated light source. Of the two variables, time and intensity, one is maintained constant to with ±2% while the other is varied in a systematic fashion over a range of at least one order of magnitude and sometimes as much as four orders of magitude (10, 000 times). Variation between steps may be as small as a factor of $\sqrt[6]{2}$ or as large as a factor of 2. A typical sensitometer (exposing device) has a range of a factor of 1000 (3.0 log units), holds exposure time constant to ±2%, and has 21 steps of a factor of $\sqrt{2}$ to cover its range. Step intervals are precise to ±3% and calibrated independently to within better than ±1%.

2) Process the material under carefully-controlled conditions of time, temperature, agitation, developer composition and developer age. The precision of this operation is usually held to ±0.03 density units.

3) Read and record the resultant optical densities on an instrument calibrated to ±0.01D and precise to ±0.02D.

4) Plot the values (commonly the averages of several readings at each density on each of several samples) as a characteristic or D log E curve. Density is plotted as a function of the log of exposure.

5) Analysis of the curve(s) yields the standard derived values of:

a) Exposure speed (log E to produce a given density or density gradient).

b) Gradient (the slope of the central portion of the curve — often called gamma).

c) Maximum density.

d) Minimum density.

e) Other less common statistics such as the shape of the "toe" or "shoulder."

Technicians skilled in sensitometric experimentation are employed in large numbers by manufacturers of photographic materials. These skills are also commonly used in industrial organizations and academic institutions that use photographic measuring techniques. These applications include spectrophotographic analysis of materials (metals, organic compounds, dyes and pigments), color photography process control, and film dosimetry of x-ray and nuclear radiation.

APPENDIX C

MASTER NEGATIVES

A master negative may be made as a "stack" of separate low density negatives, one for each isodose contour, all registered carefully, or as a "single sheet" on which a series of exposures of different contours have been made from the exposure masks (cut-outs). For both kinds of negatives it is necessary to prepare a series of opaque cut-outs, one for each isodose contour. The separate procedures are as follows:

1) Master Negative as a Stack of Low Density Negatives.

a) Each cut-out, when used as a mask produces a negative with a very low density (basic film density is approximately 0.10) center and a slightly higher surround. For a pattern of 11 steps: 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, there will be 10 negatives in the stack.

b) The positive pattern density of 2.0D (1000 r) will be achieved by exposing through the 10 center areas, each of base density; the 1.8D step (900 r) by exposing through nine base density areas and the slightly higher surround created by the 1000 r cut-out;.........the 0.4D step (200 r) by exposing through two base density areas and 8 slightly higher surrounds created by the 1000 r, 900 r, 800 r, 700 r, 600 r, 500 r, 400 r, and 300 r cut-outs; the 0.2D step (100 r) by exposing through one base density and 9 slightly higher surrounds created by the 1000 r, 900 r, 800 r, 700 r, 600 r, 500 r, 400 r, 300 r, and 200 r cut-outs; and the 0.1D (50 r) positive pattern density will be achieved by exposing through all ten surrounds. (The outline of the 50 r contour is not used in exposing, but is used for cutting the pattern out of the sheet of exposed and processed film.)

c) If the photographic materials were true "straight line" materials, each of the cut-outs would be printed to the same surround density. For materials with a gamma equal to 1.00 and a base density equal to 0.10, the surround in each case would have a density of 0.20. It is because the D log E characteristics of the photosensitive materials are not exactly linear, because it is difficult to achieve an average gamma equal to 1.00, and because reproducibility within small limits is essential that this process requires the skill of a person experienced in sensitometric methods.

The desired stack density for each contour may be determined from the D log E curve of the positive material. The slightly higher surround density for each individual negative mask is then determined to a first approximation by subtraction.

d) It has been found most efficient to make the negatives of the separate contours, stack them in approximate register, make a trial positive and then measure its density. An evaluation of the trial positive will indicate whether the negative is good enough to use directly, whether it can be used by doctoring the positive exposure or processing, or whether it is not suitable because one or more steps need to be modified. Precise registry need not be made until the negative densities, and positive exposing and processing are proven acceptable.

e) As noted above, an acceptable trial positive was produced on the fourth attempt.

2) Master Negative as a Single Sheet With Multiple Exposures

a) For this technique, it is necessary to develop a pin register platten for aligning a series of transparent sheets, each of which has drawn or pasted on it an opaque area corresponding to a given contour outline.

b) After obtaining the positive characteristic D log E curve for varying density steps (at constant time) it is then necessary to develop a D log E curve for a series of interrupted time exposures. The range required is in the order of 3.0 density units or 1000 to 1. Since this range is somewhat impractical, considering a minimum precise time of 10.0 seconds, it is desirable to use at least two intensity levels. One series of 11 steps in $\sqrt{2}$ intervals might be 10, 14, 20, 28, 40, 56, 80, 112, 160, 224 and 320 seconds. If the second intensity were 32.0 times greater, the desired range would be realized with exposures ranging from 10 seconds to 5 minutes and 20 seconds. A very precise timer accurate to 0.02 seconds at 2 seconds could be used to shorten the time scale, but a double intensity system would still be necessary.

c) Either range of times is still great enough to introduce some reciprocity failure so that several series of exposures may be necessary to establish a workable curve.

The first stack master negative was much easier to make than was the first single sheet negative. The latter system required even more precise control of the exposing and processing steps. It now seems that the single sheet negative is a practical method only if either of the following conditions exist.

1) A large number of (more than 10) masters are to be made.

2) Many hundreds of positive patterns are to be made.

In the former situation the exposure times should be the same for the different sets of masks so that the lengthy set-up time can be justified by the expected savings in making successive masters. In the latter situation the more rugged single sheet master negative may be less prone to damage from the normal handling encountered in making many hundreds of prints.

CHAPTER 6

FALLOUT LEVELS OVER THE UNITED STATES

The wind conditions and fallout model used in this analysis are described in Chapters 3 and 4 respectively. The levels shown should not be taken too literally in an absolute sense, but rather as a relative indication of the extent of the fallout hazard in the different parts of the country resulting from logically conceived attacks on our retaliatory air defense, and industrial potential.

6.1 FALLOUT FROM COMBINATION ATTACK

6.1.1 Winter Wind Conditions

Figures 6.1 to 6.8 show the accumulated 2-day dose levels that might result from the 4080-MT (2720 fission megatons) attack on both military and industrial targets in the U. S. described in Chapter 2. As a result of this attack, 55% of the country was found to be contaminated to a 2-day dose level of 100 r or greater. (See Figure 6.19) In the heavily-populated areas of OCDM Regions 1 and 2, 75% of the land area would be contaminated to this level or more. (See Figure 6.20.) After taking into account the probable variations in wind direction, the areas which still have a high probability of having less than a 100 r, 2-day dose are as follows:

Region 1:	None
Region 2:	Less than 5%
Region 3:	Less than 10%
Region 4:	The eastern shore of Lake Michigan, 60 to 100 miles north of Muskegon and east of that shoreline
Region 5:	Less than 25%
Region 6:	Most of Wyoming; western quarter of Colorado; northern third of South Dakota
Region 7:	The northeastern quarter of Nevada; the southern half of Utah; and the northern coast of California
Region 8:	The central region of Idaho; and the coast of Oregon and Washington.

There is no place in the continental United States so far from the targets tabulated that no fallout could reach it if we allowed for the appropriate wind direction (for the average wind velocities listed). There are large areas in Figures 6.1 to 6.8, however, which are seen to be free of fallout, but it is possible for wind shifts to place fallout over most of these sections, although in many cases probably not more than a 100 to 200 r 2-day dose.

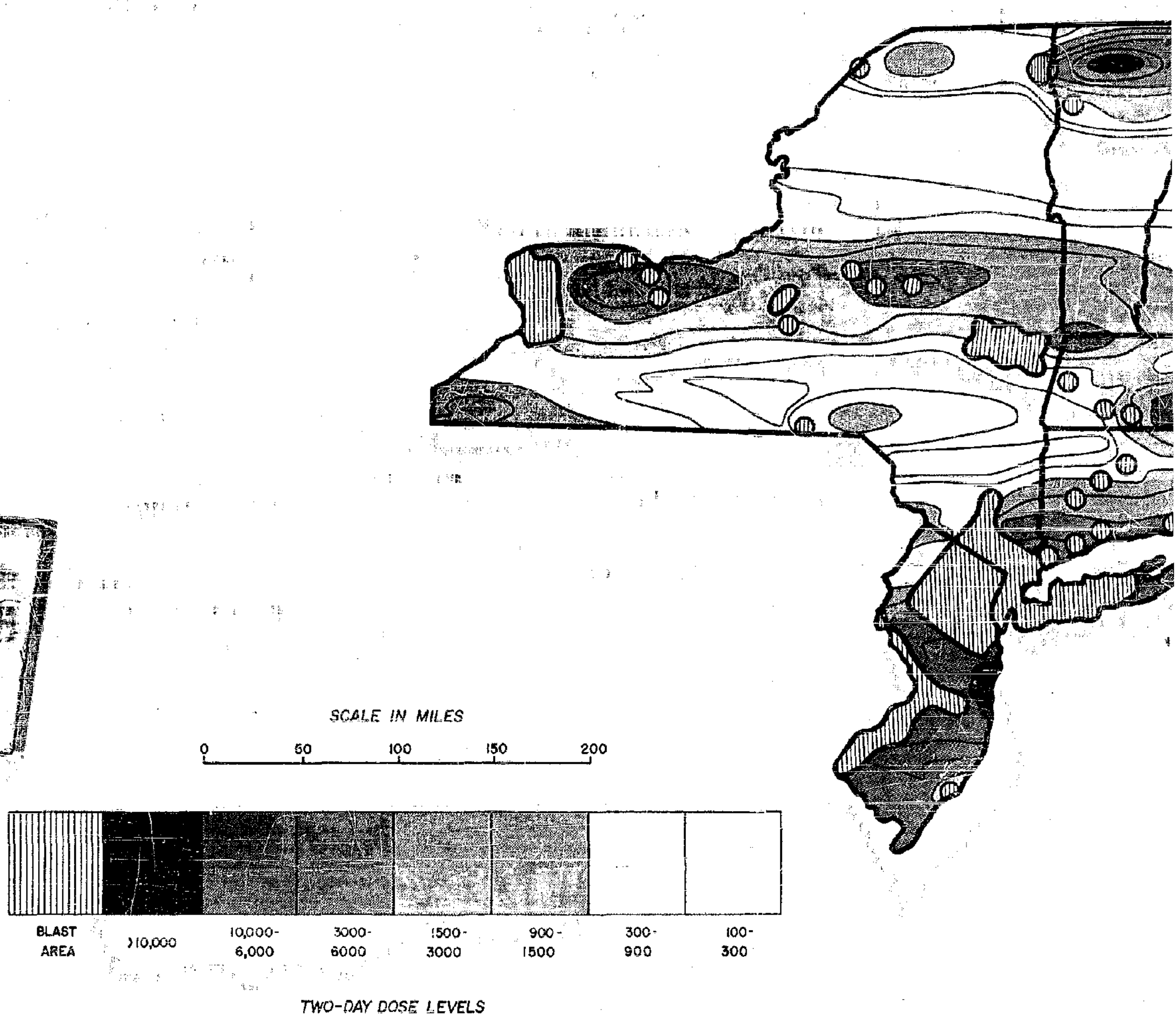
No area 300 miles or more from the nearest industrial-population target was found to receive more than 900 r over two days. Also, any point 100 miles from a target on which no more than two 5-MT weapons were dropped, would not expect to receive over a 900 r 2-day dose.

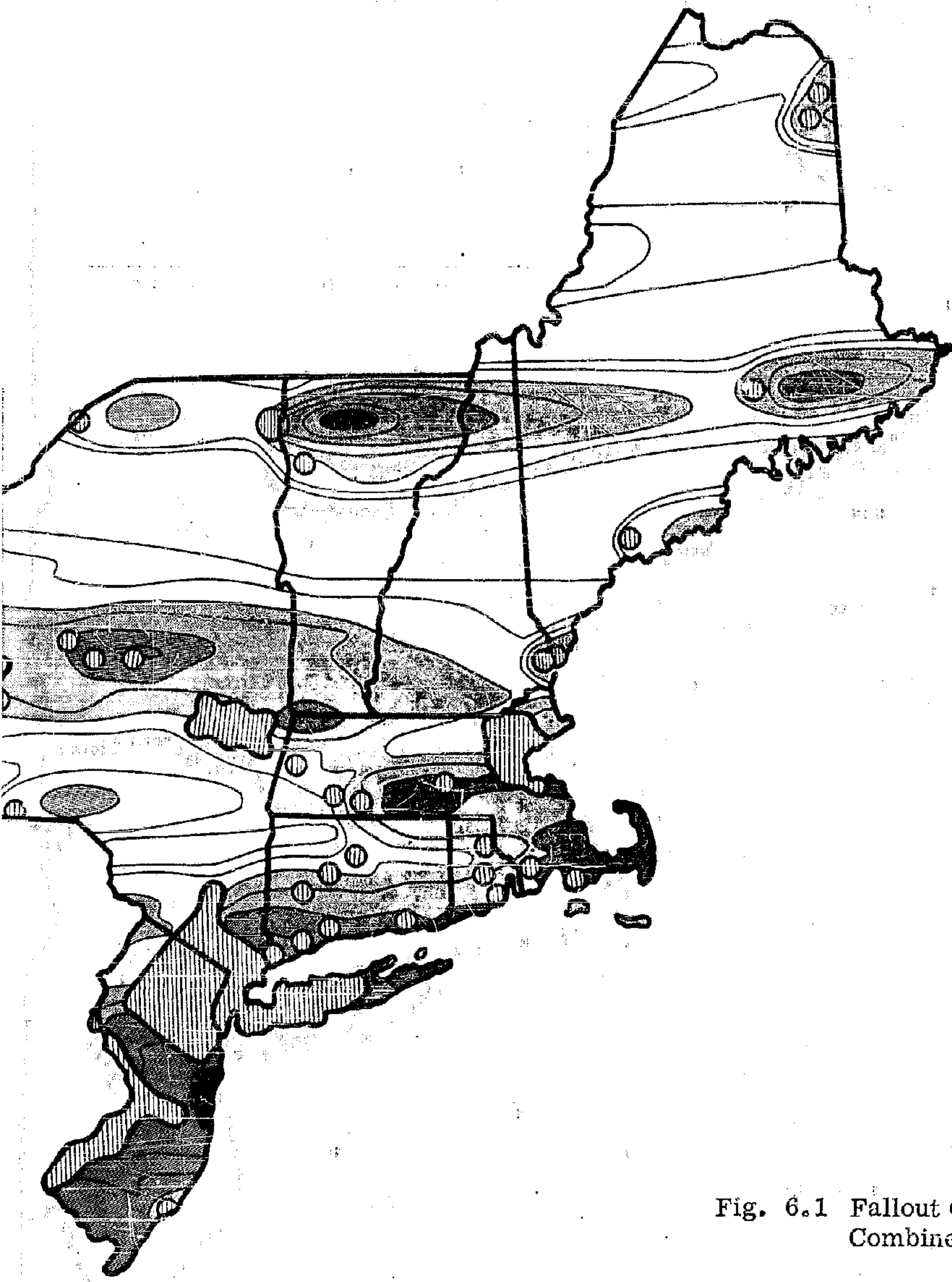
Very intense fallout levels of 6000 to 10,000 r 2-day dose occur downwind of the major industrial, population and military centers. Areas of 10,000 r and greater were found to exist only around the Los Angeles and Philadelphia areas, and downwind of ICBM launching locations where eight 5-MT's were dropped. Areas around Chicago and New York City would have had 10,000 r if the wind direction had not placed the heaviest fallout over bodies of water. Levels of 10,000 r and higher would exist around other large industrial-population centers if the ground zeros had been spaced closer than the 14 miles between centers chosen for the priority-one industrial targets.

The steepest gradient in the heaviest fallout areas is in the crosswind direction near ground zero where the level decreases by a factor of 2 for every 2 to 3 miles. The minimum downwind gradation from 6000 to 3000 r was found to be about 25 miles. In the lighter fallout areas, the minimum gradient from 200 r to 100 r can occur over a distance of up to 200 miles in the downwind direction.

6.1.2 Summer Wind Conditions

Figures 6.9, 6.10, and 6.11 illustrate the fallout situation that might result from the 4080-MT (2720 fission megatons) attack on the United States during the summer season for Regions 3, 4, and 8 respectively. Because of the lower wind speed during the summer season, the curve of 2-day dose vs. area covered is much steeper than the corresponding one for the winter wind (See Figure 6.19.) The reason for this is that the fallout from each weapon is concentrated near ground zero with the result that the areas covered to a 2-day dose of 1000 r or less are smaller while those having more than 1000 r are larger than the corresponding areas under winter wind conditions.


SCALE IN MILES
0 50 100 150 200
BLAST AREA
>10,000
10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS



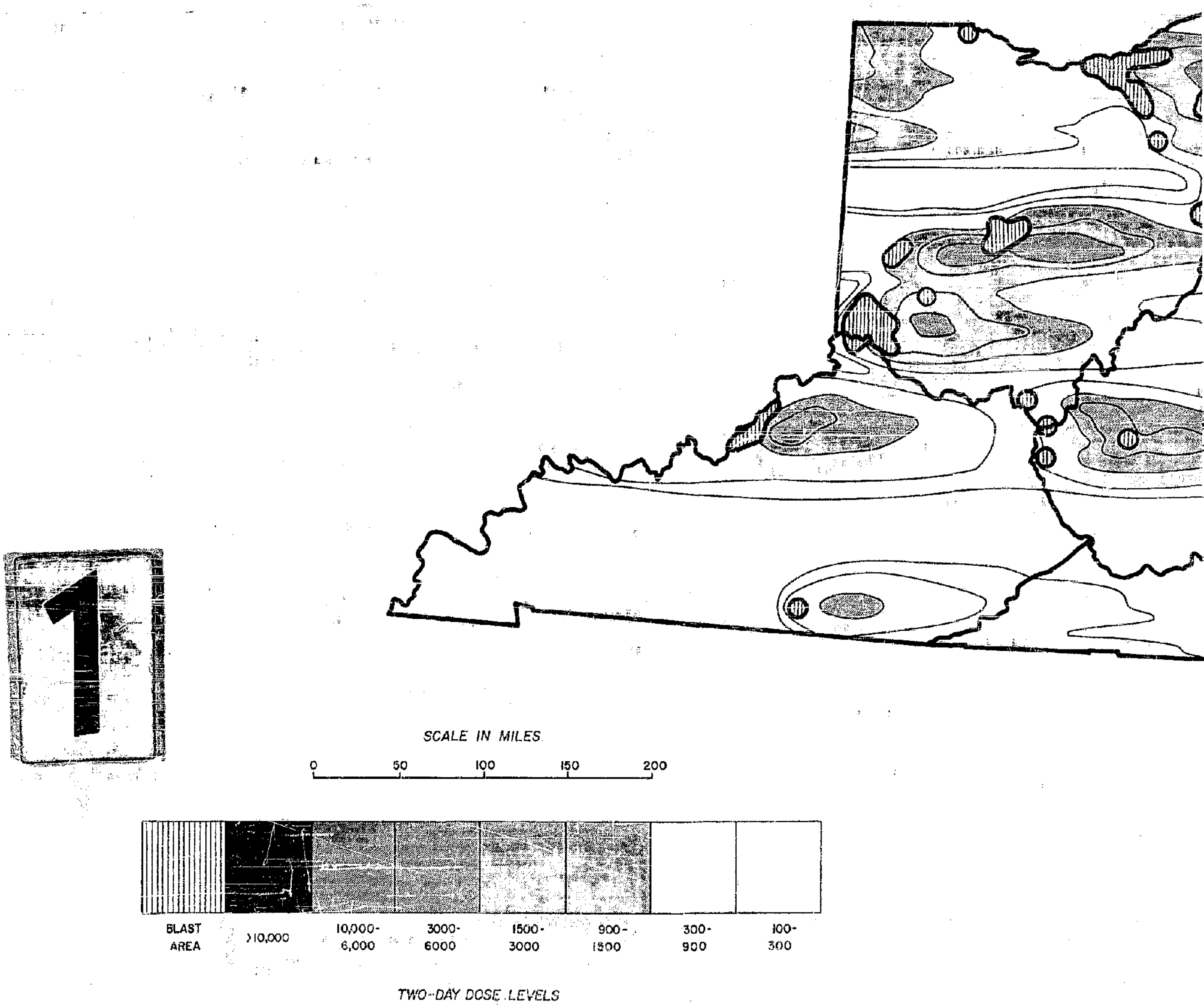
2

Fig. 6.1 Fallout Over Region 1 From Combined Attack in Winter

Megatons (Fission) on Military and Industrial Targets in OCDM Region 1 = 370

Megatons (Fission) on U. S. = 2720

Mean Seasonal Winter Wind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SCALE IN MILES
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BLAST AREA
>10,000
10,000-6,000
3000-6000
1500-3000
900-1800
300-900
100-300
TWO-DAY DOSE LEVELS

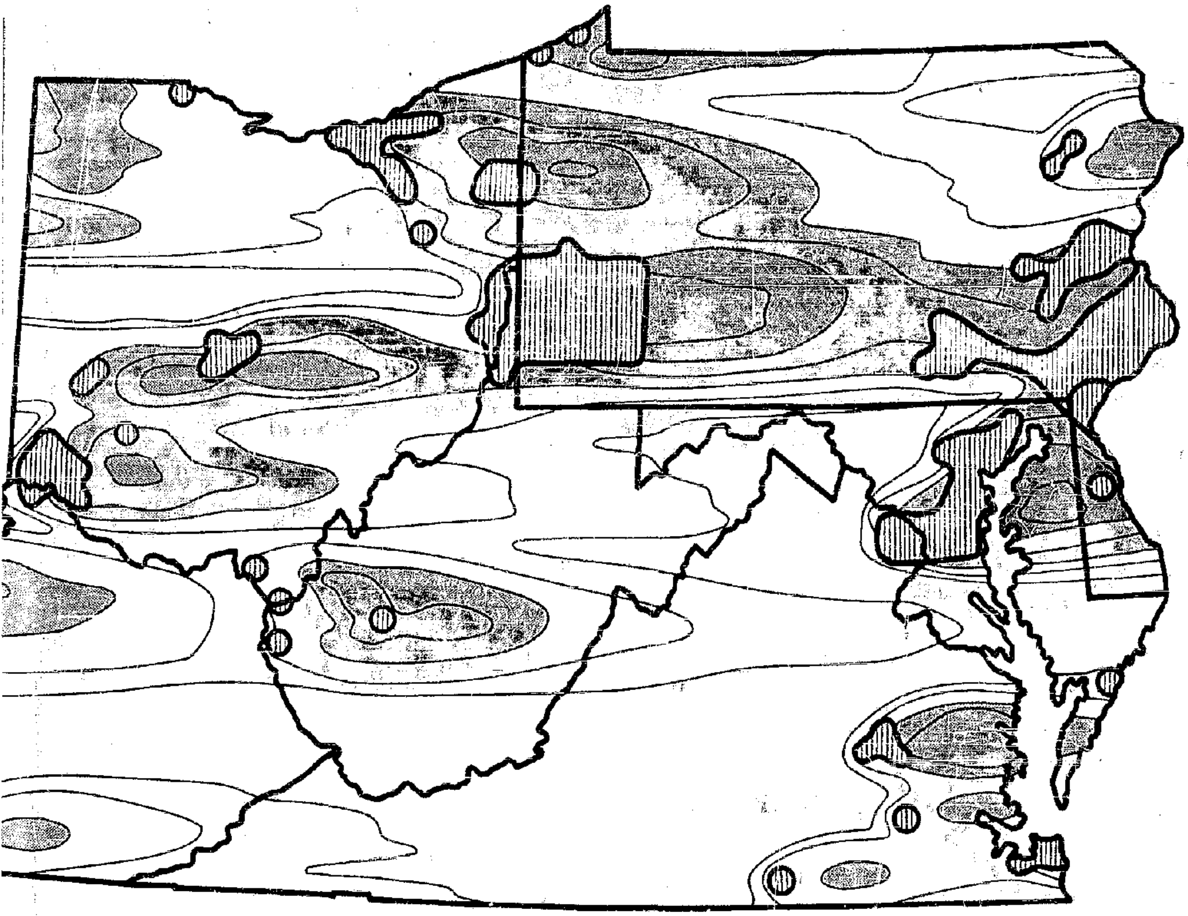


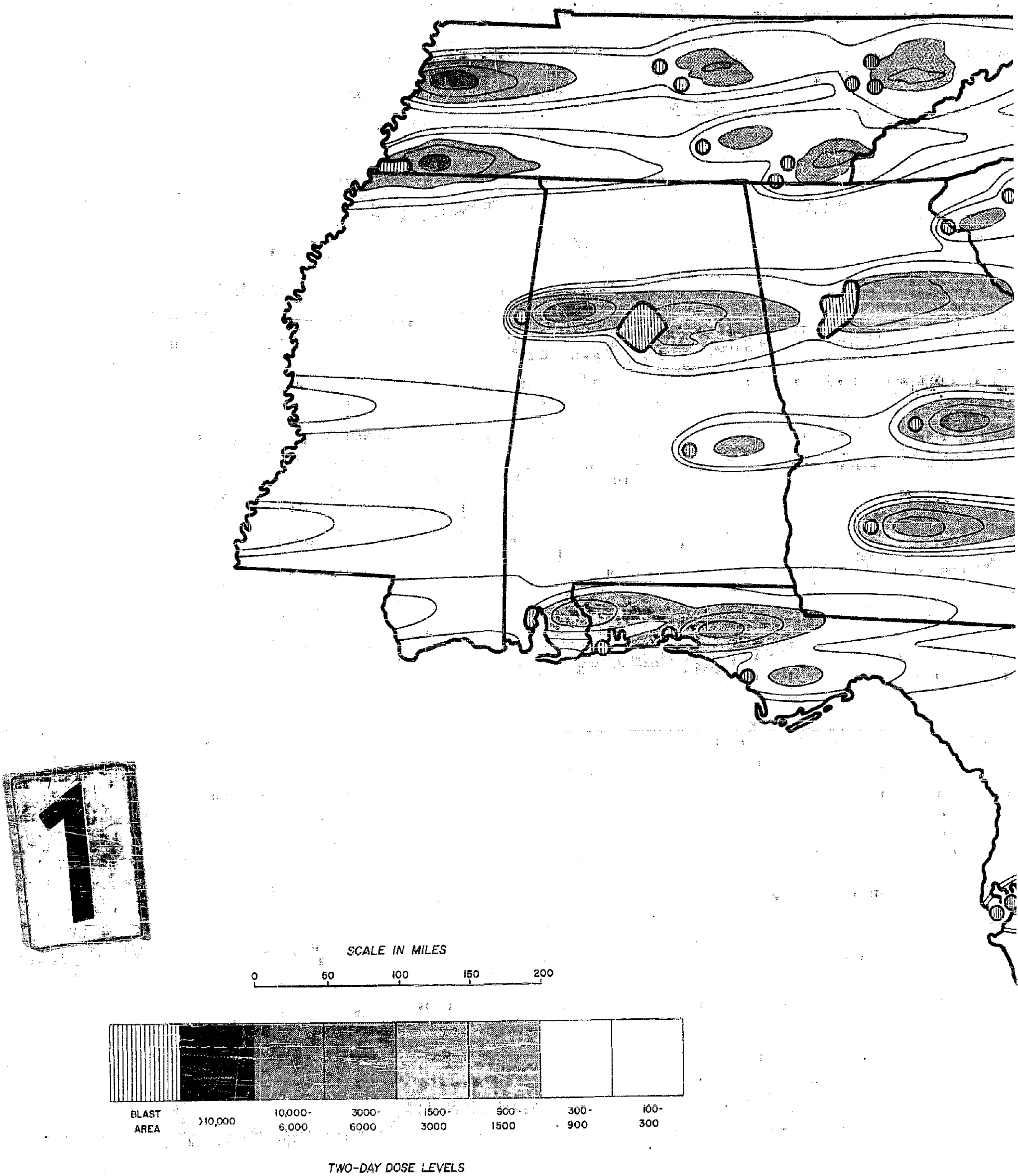
Fig. 6.2 Fallout Over Region 2 From Combined Attack in Winter

2

Megatons (Fission) on Military and Industrial Targets in OCDM Region 2 = 460

Megatons (Fission) on U. S. = 2720

Mean Seasonal Winter Wind



1
SCALE IN MILES
0 50 100 150 200
BLAST AREA
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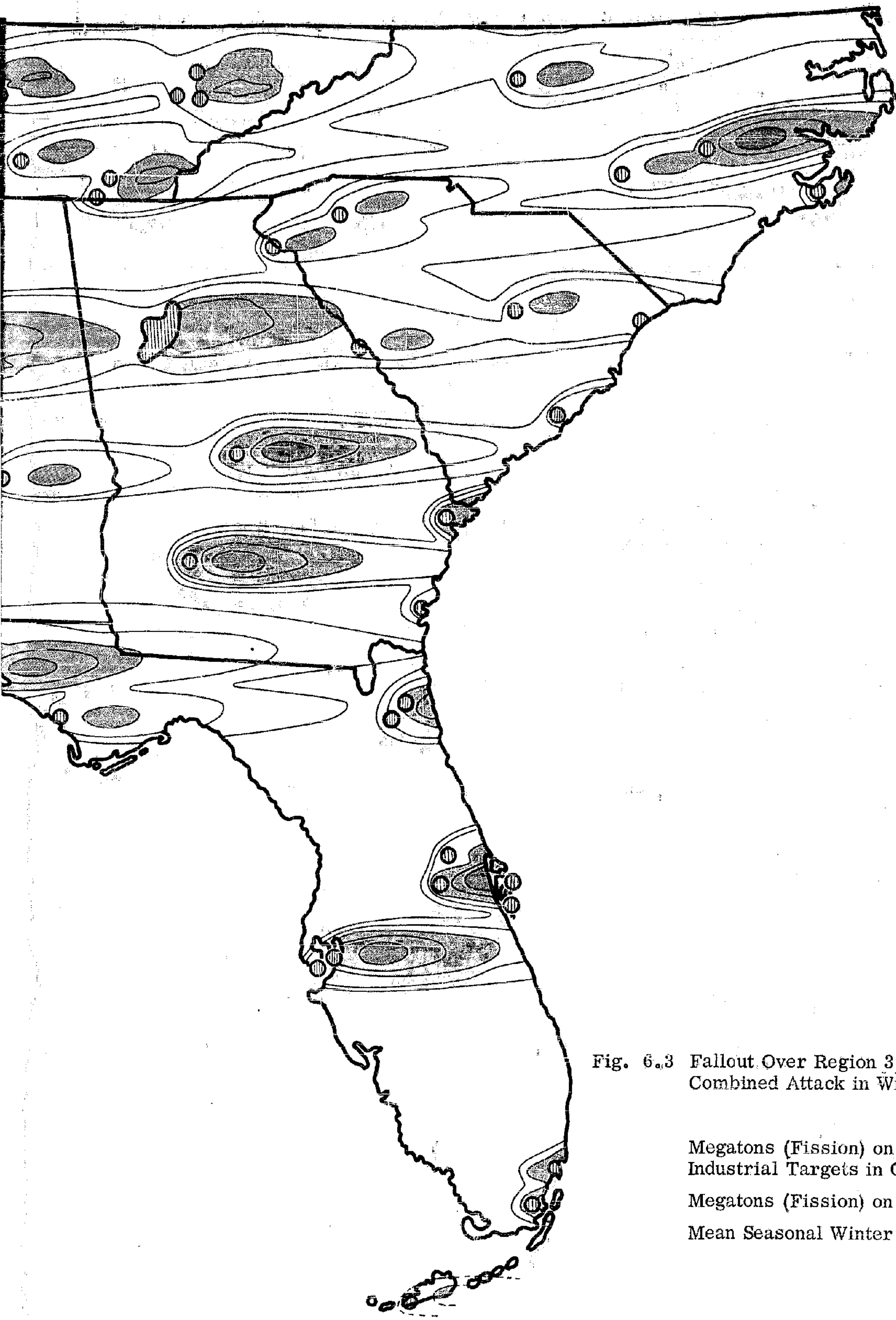
10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS



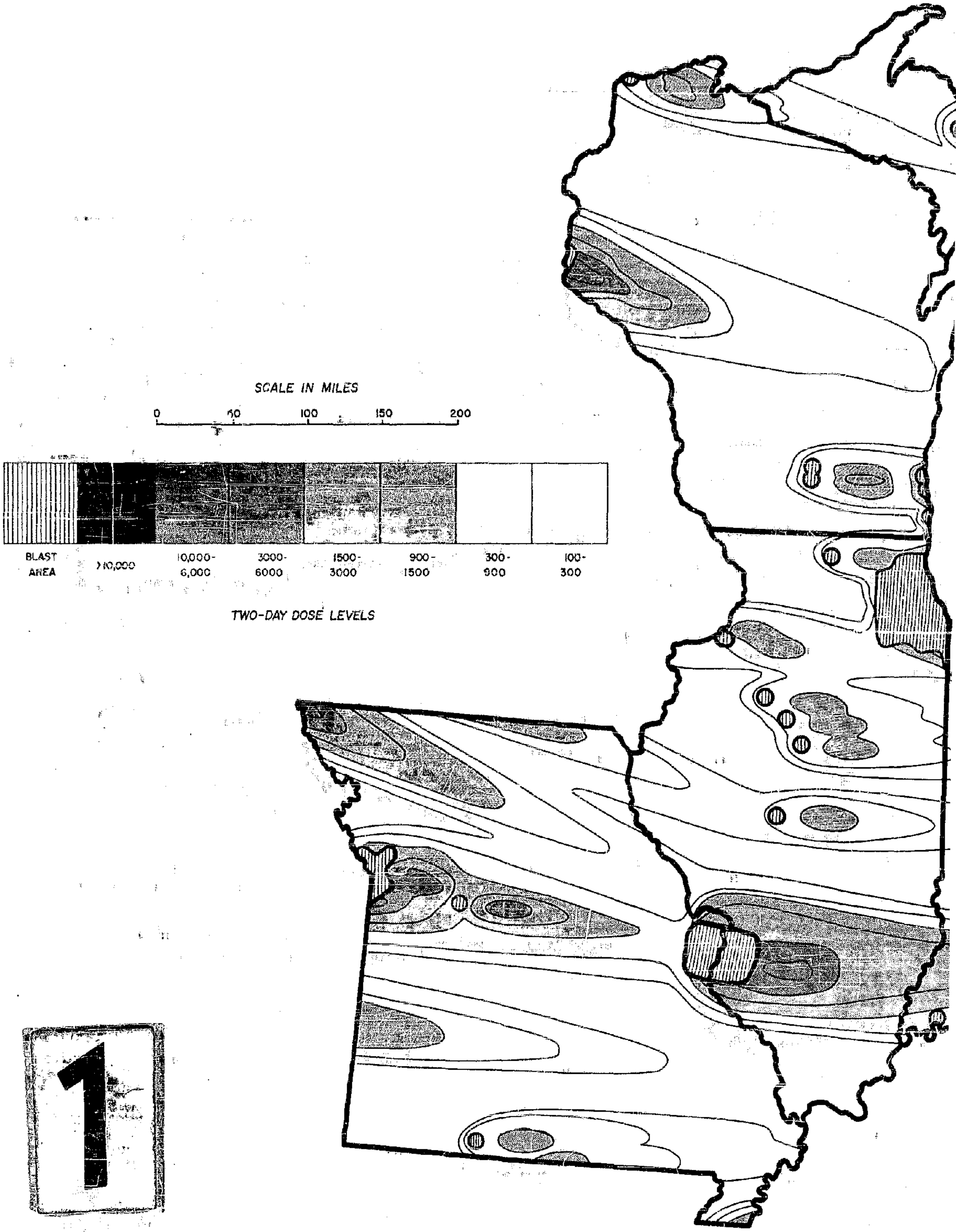
2

Fig. 6.3 Fallout Over Region 3 From Combined Attack in Winter

Megatons (Fission) on Military and Industrial Targets in OCDM Region 3 = 240

Megatons (Fission) on U. S. = 2720

Mean Seasonal Winter Wind


SCALE IN MILES
0 50 100 150 200
BLAST AREA
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10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS

1

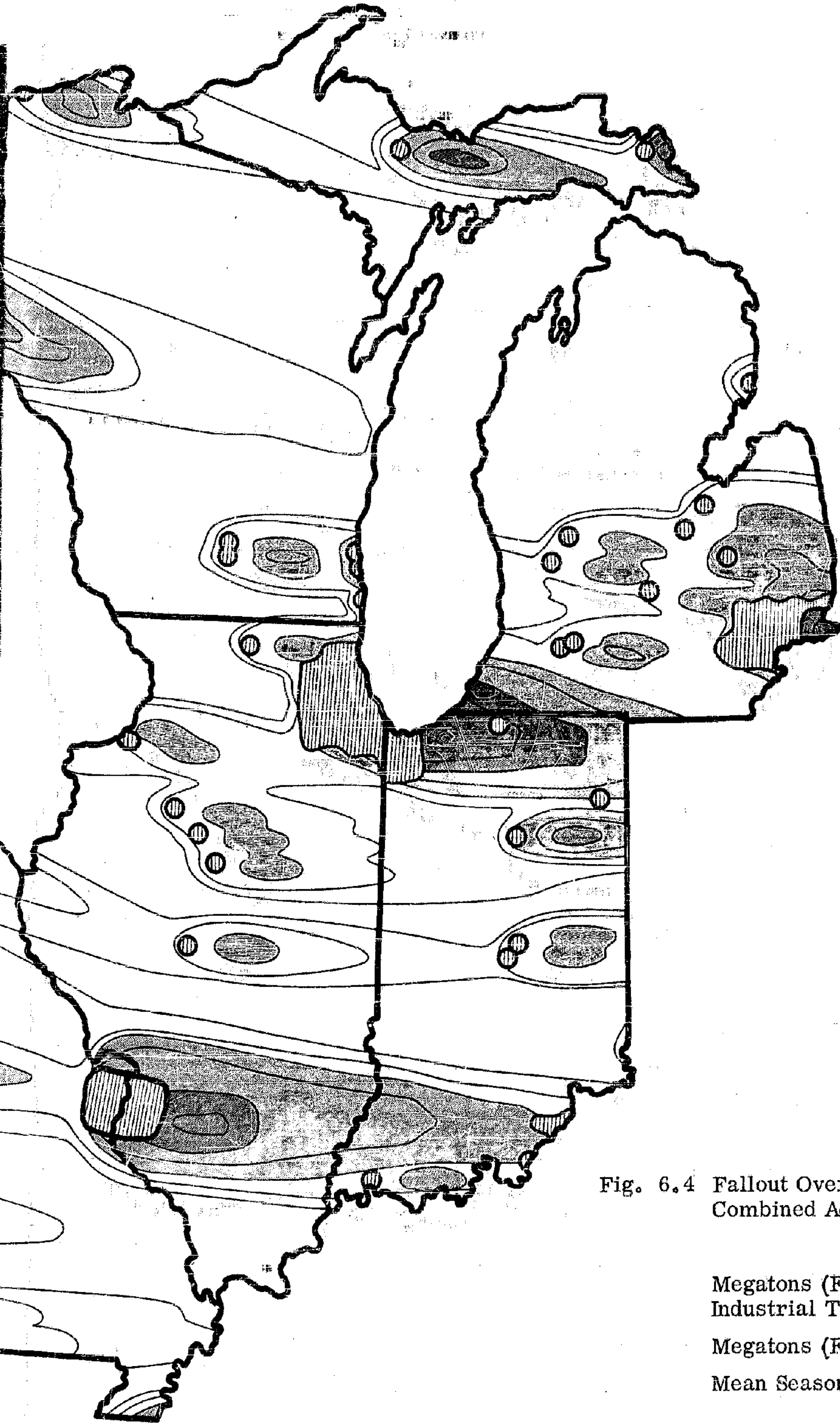
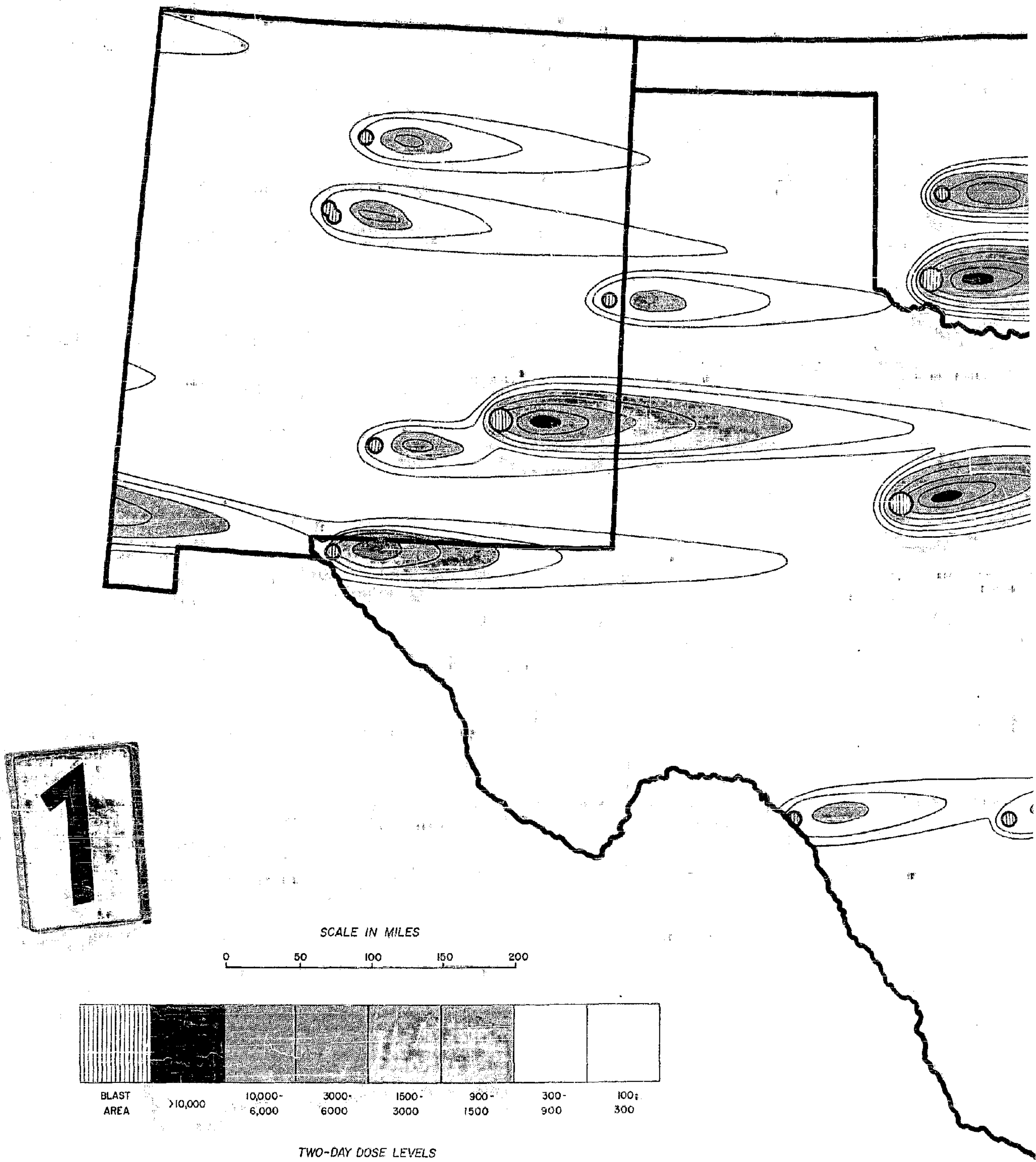


Fig. 6.4 Fallout Over Region 4 From Combined Attack in Winter

Megatons (Fission) on Military and Industrial Targets in OCDM Region 4 = 340

Megatons (Fission) on U. S. = 2720

Mean Seasonal Winter Wind


1
SCALE IN MILES
0 50 100 150 200
BLAST AREA
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3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS

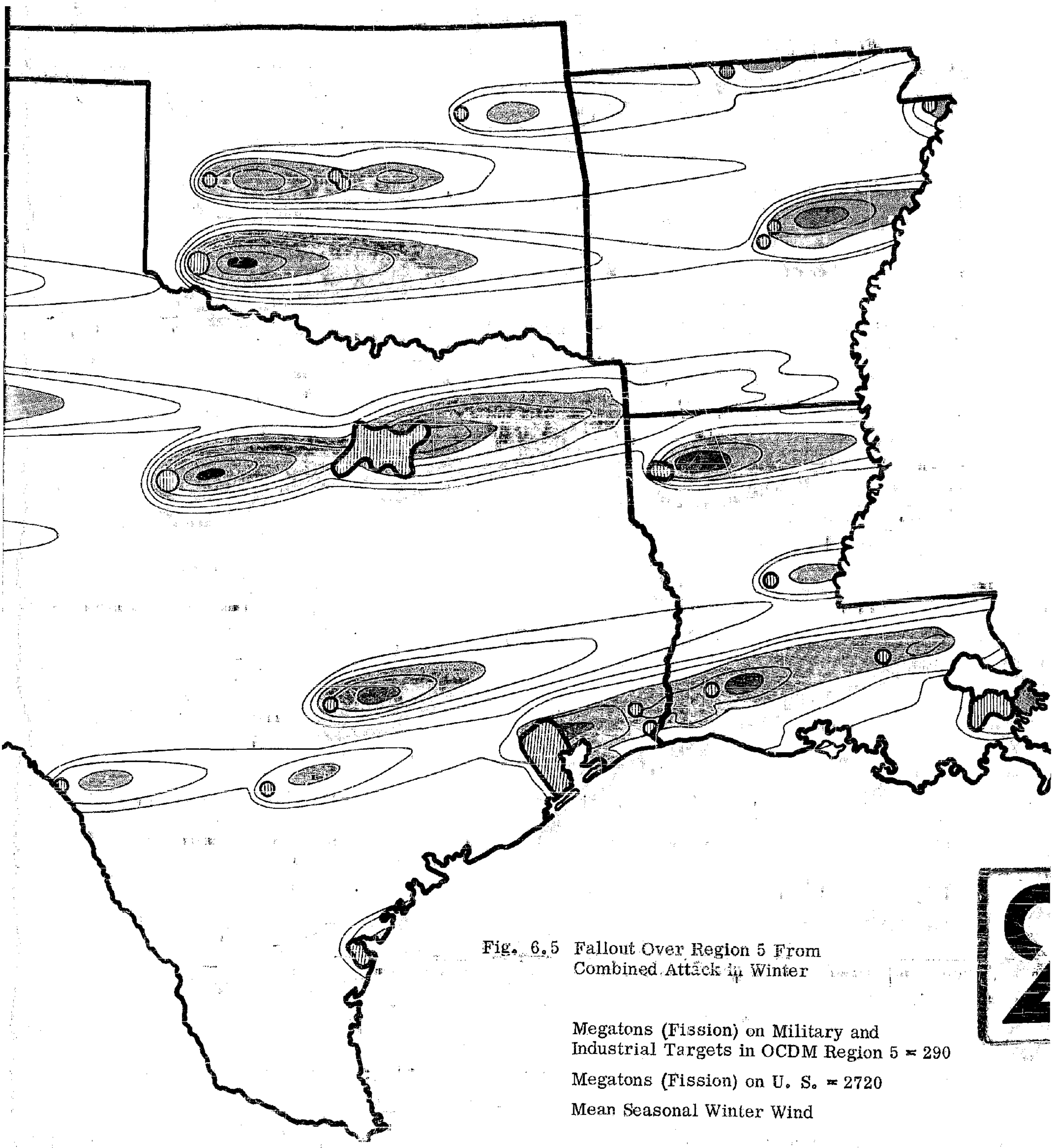
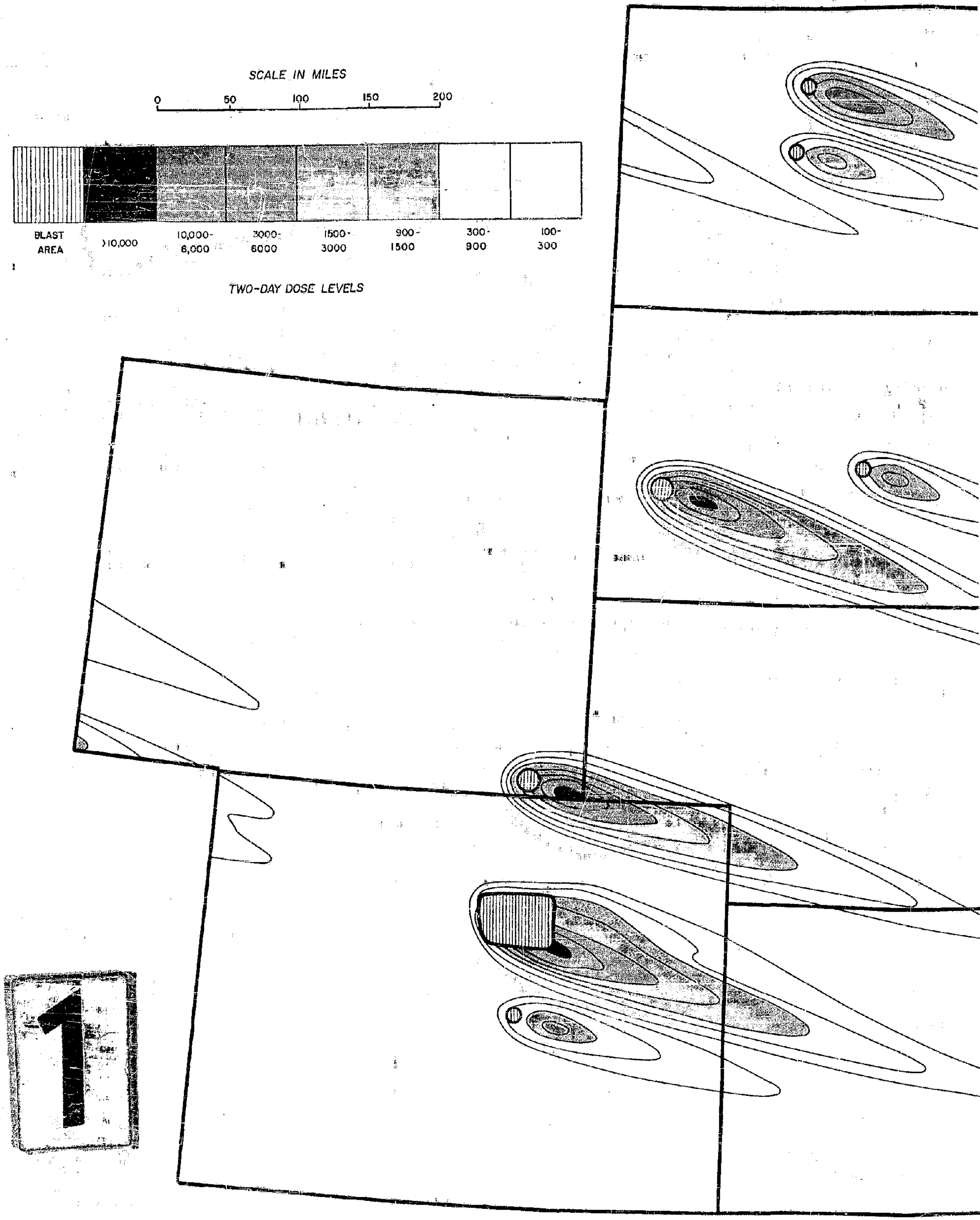


Fig. 6.5 Fallout Over Region 5 From Combined Attack in Winter

Megatons (Fission) on Military and Industrial Targets in OCDM Region 5 = 290

Megatons (Fission) on U. S. = 2720

Mean Seasonal Winter Wind


SCALE IN MILES
0
50
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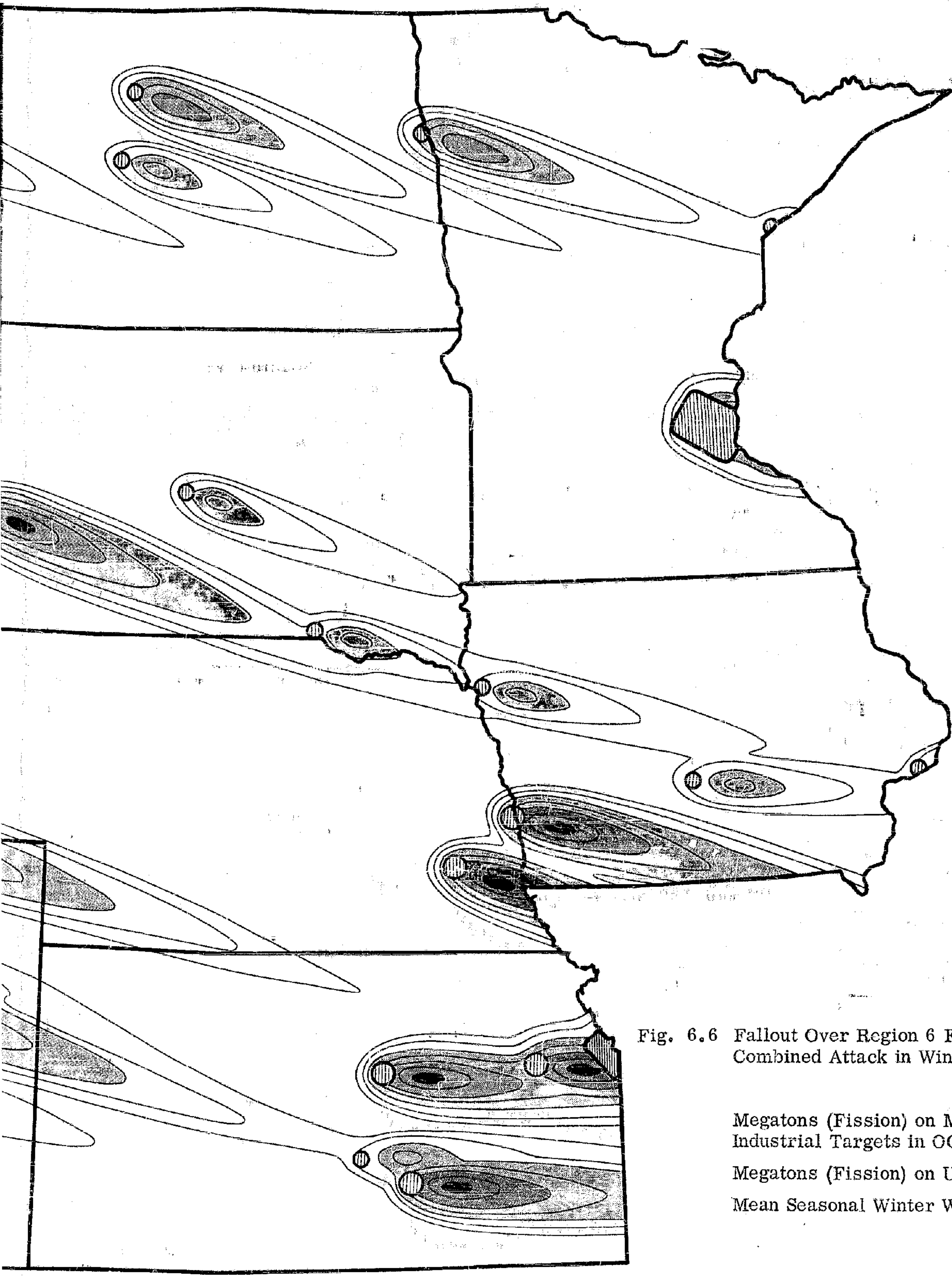
150
200
BLAST AREA
>10,000
10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS
1



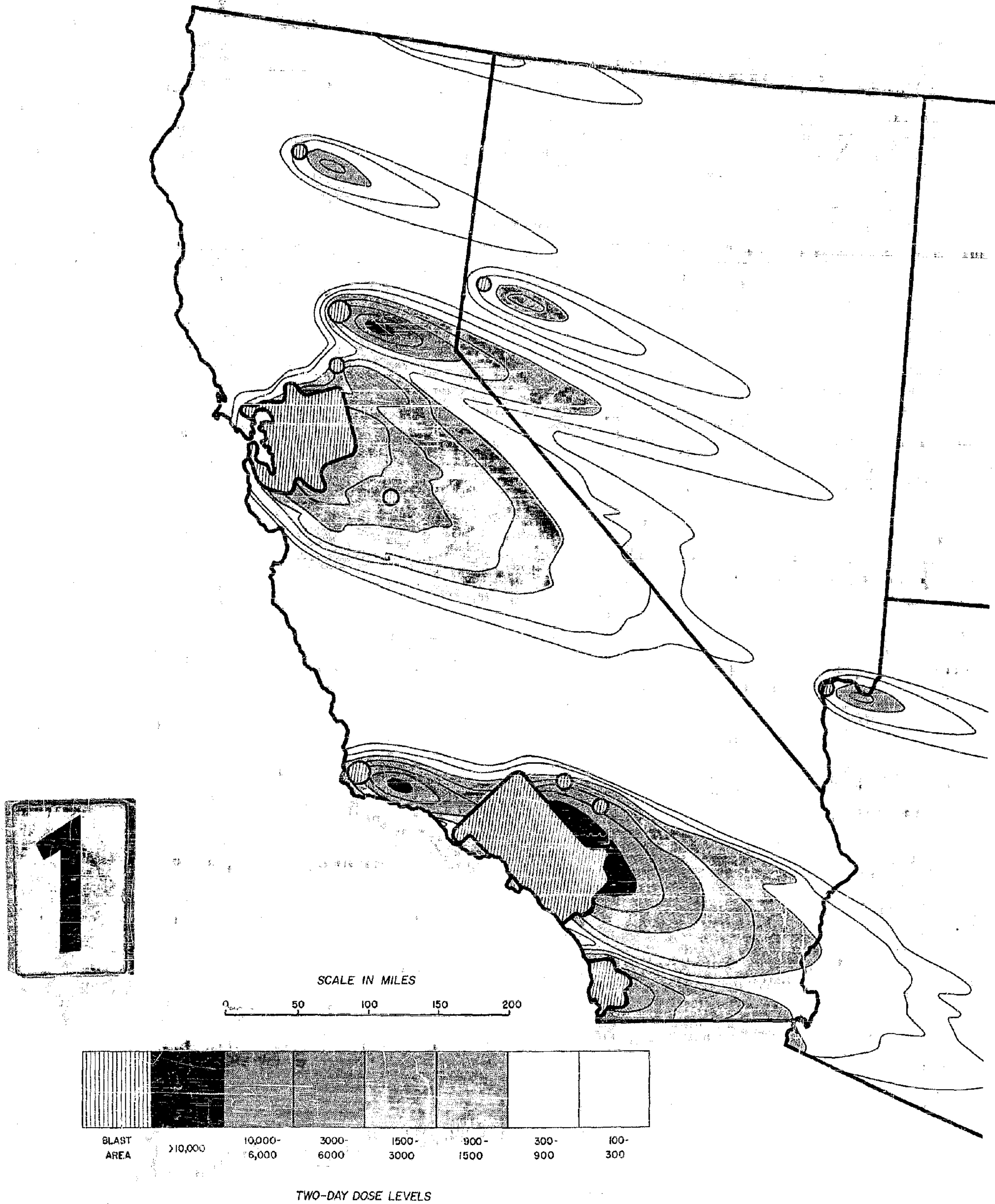
2

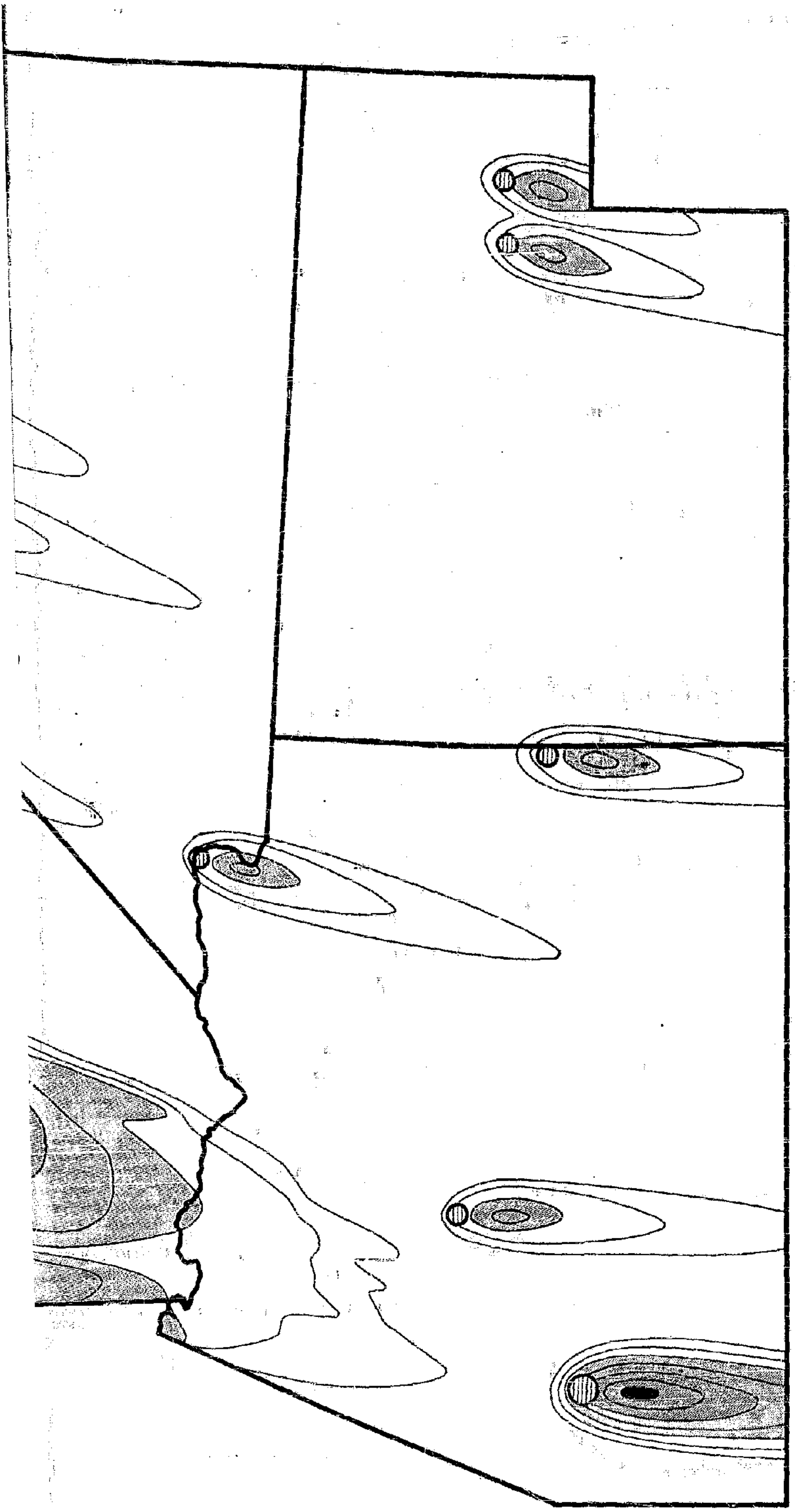
Fig. 6.6 Fallout Over Region 6 From Combined Attack in Winter

Megatons (Fission) on Military and Industrial Targets in OCDM Region 6 =

Megatons (Fission) on U. S. = 2720

Mean Seasonal Winter Wind


1
SCALE IN MILES
0 50 100 150 200
BLAST AREA
>10,000
10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS



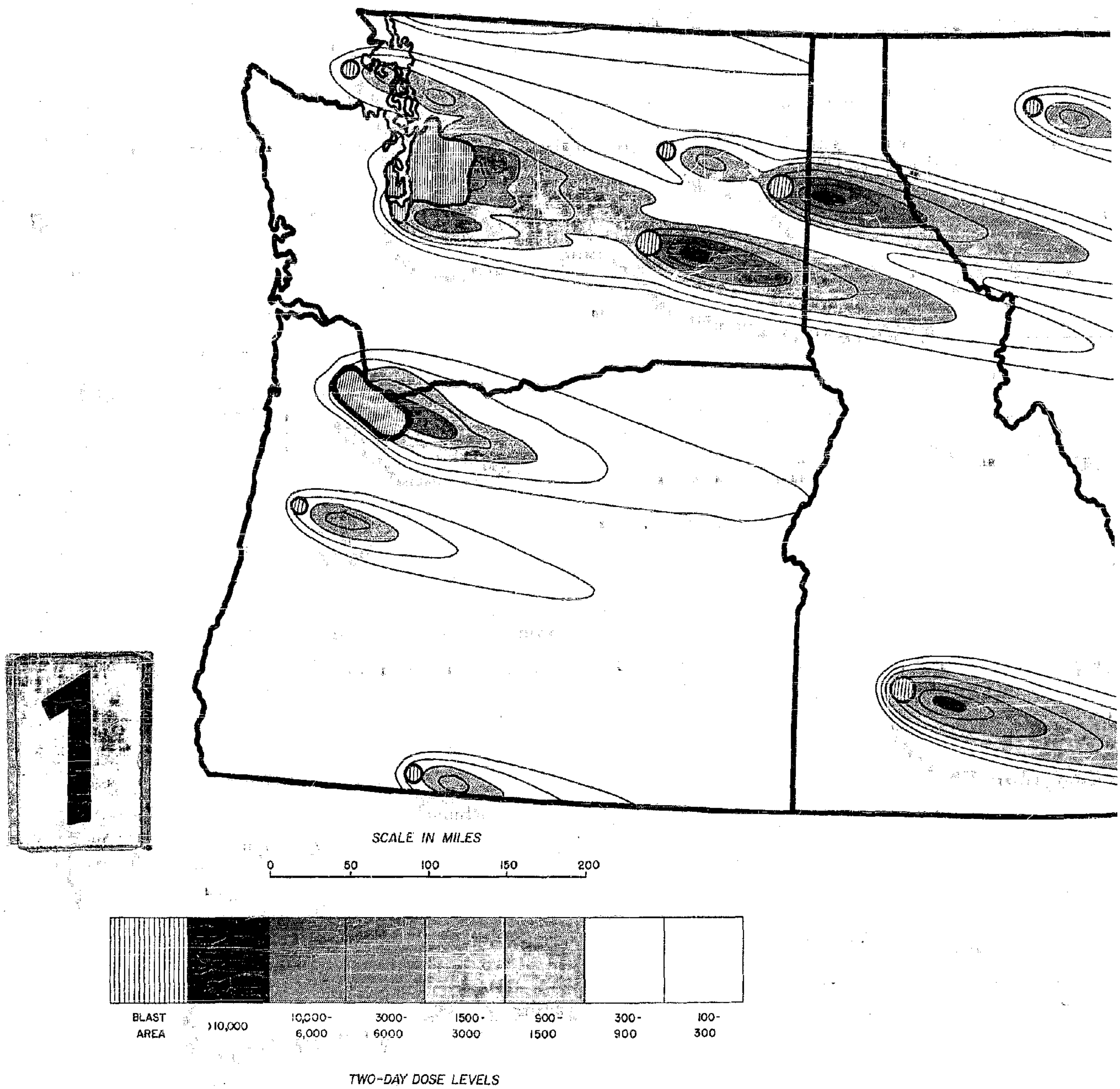
2

Fig. 6.7 Fallout Over Region 7 From Combined Attack in Winter

Megatons (Fission) on Military and Industrial Targets in OCDM Region 7 =

Megatons (Fission) on U. S. = 2720

Mean Seasonal Winter Wind


1
SCALE IN MILES
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50
100
150
200
BLAST AREA
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10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS

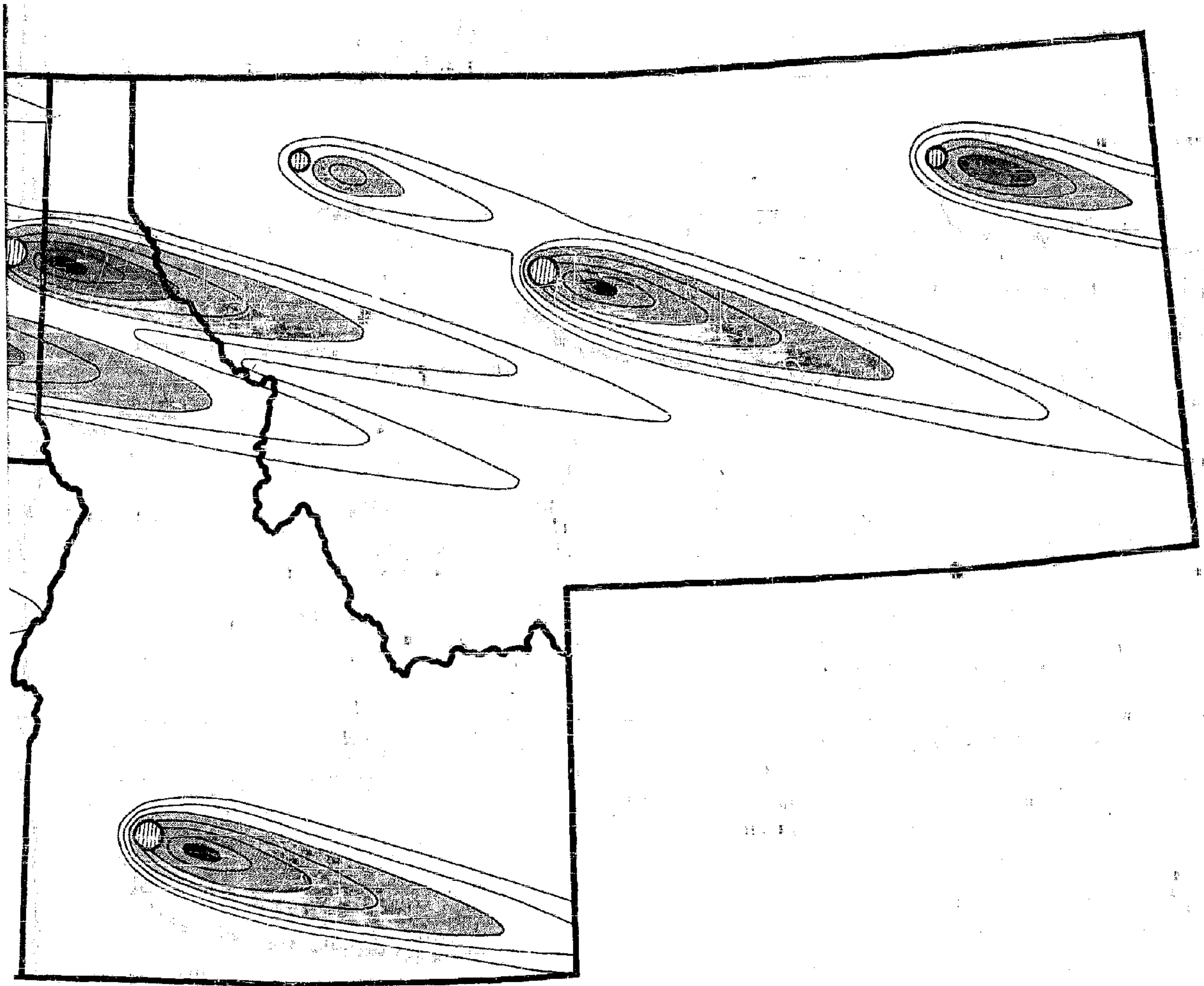
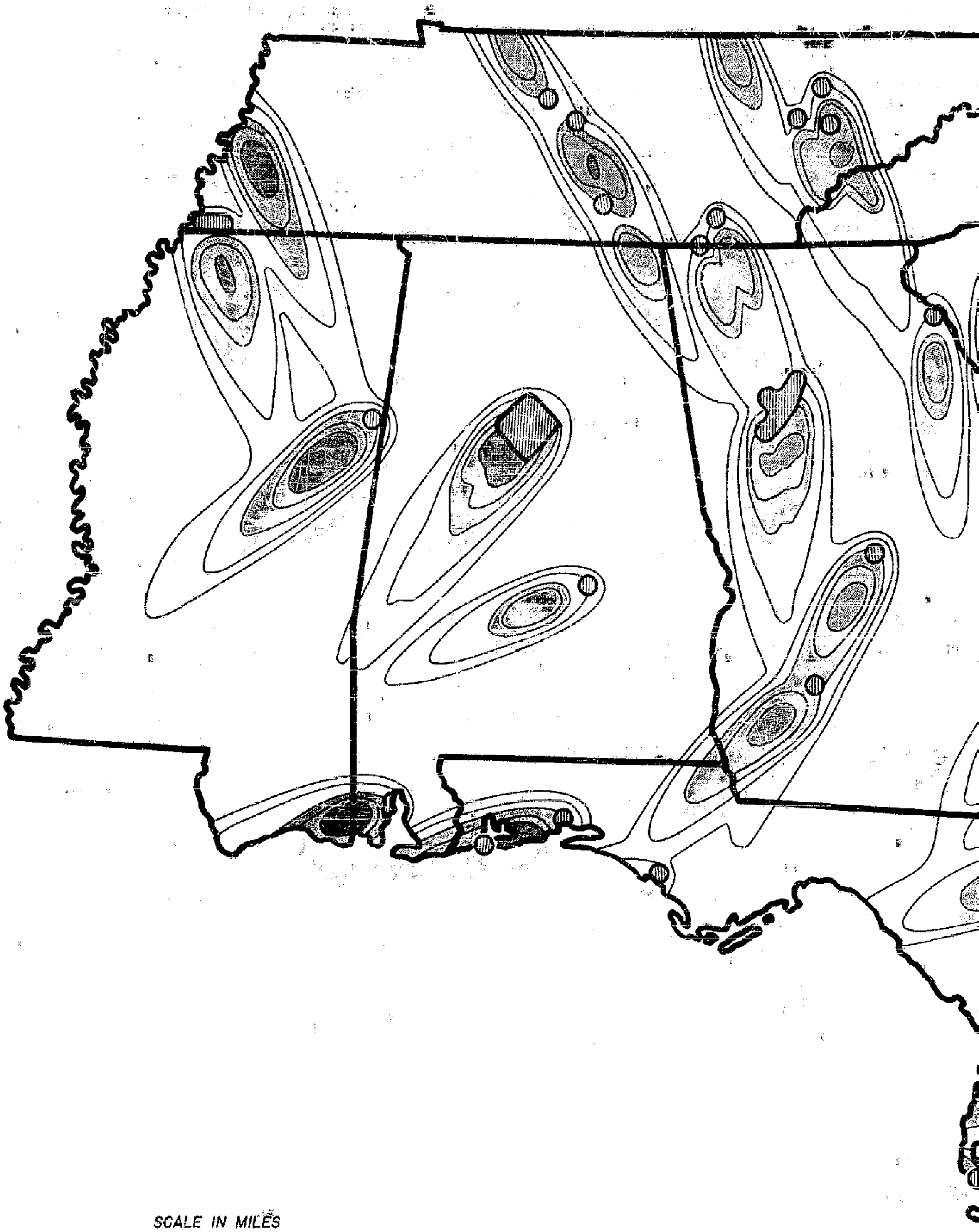


Fig. 6.8 Fallout Over Region 8 From Combined Attack in Winter

Megatons (Fission) on Military and Industrial Targets in OCDM Region 8 = 210

Megatons (Fission) on U. S. = 2720

Mean Seasonal Winter Wind



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SCALE IN MILES

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TWO-DAY DOSE LEVELS

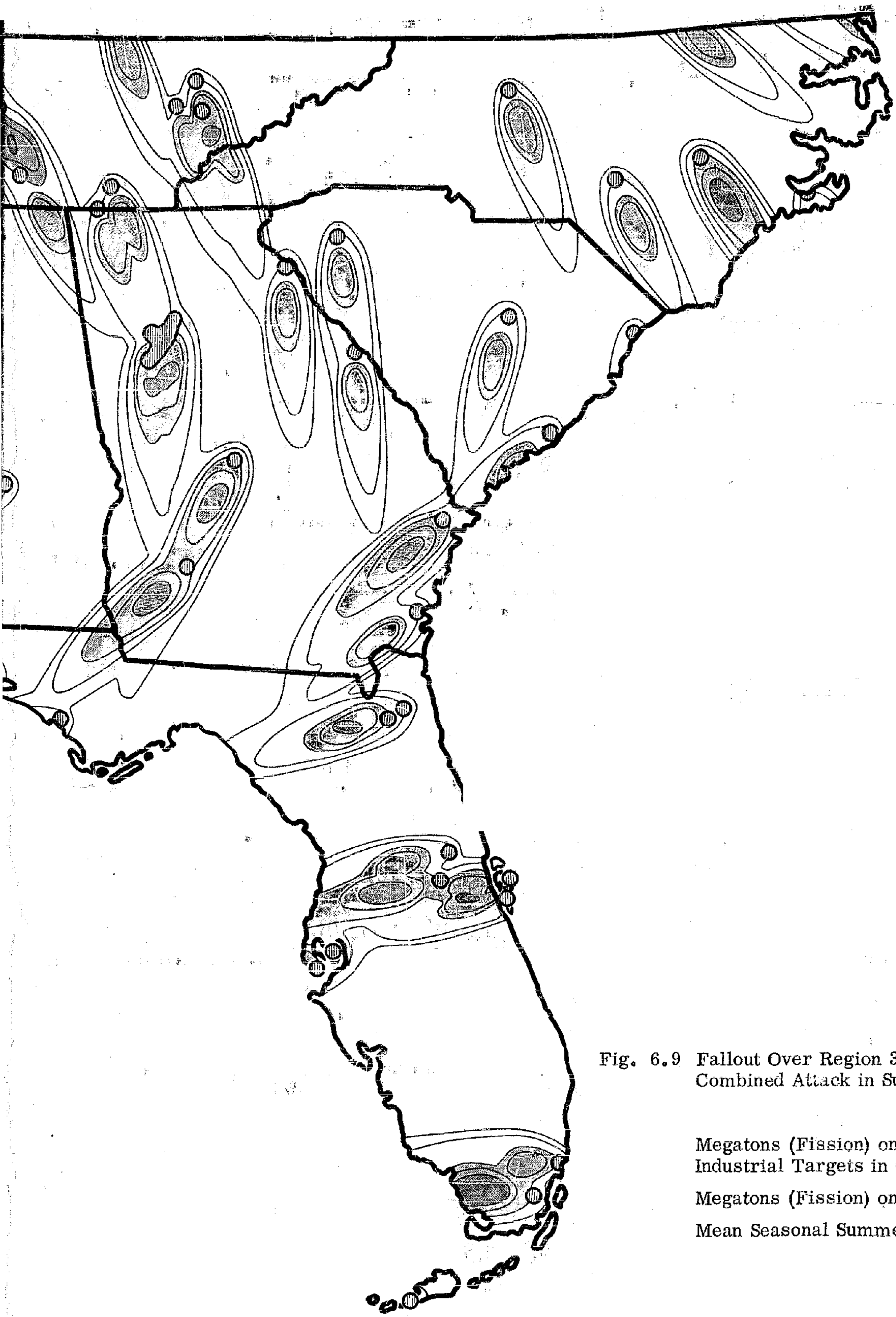
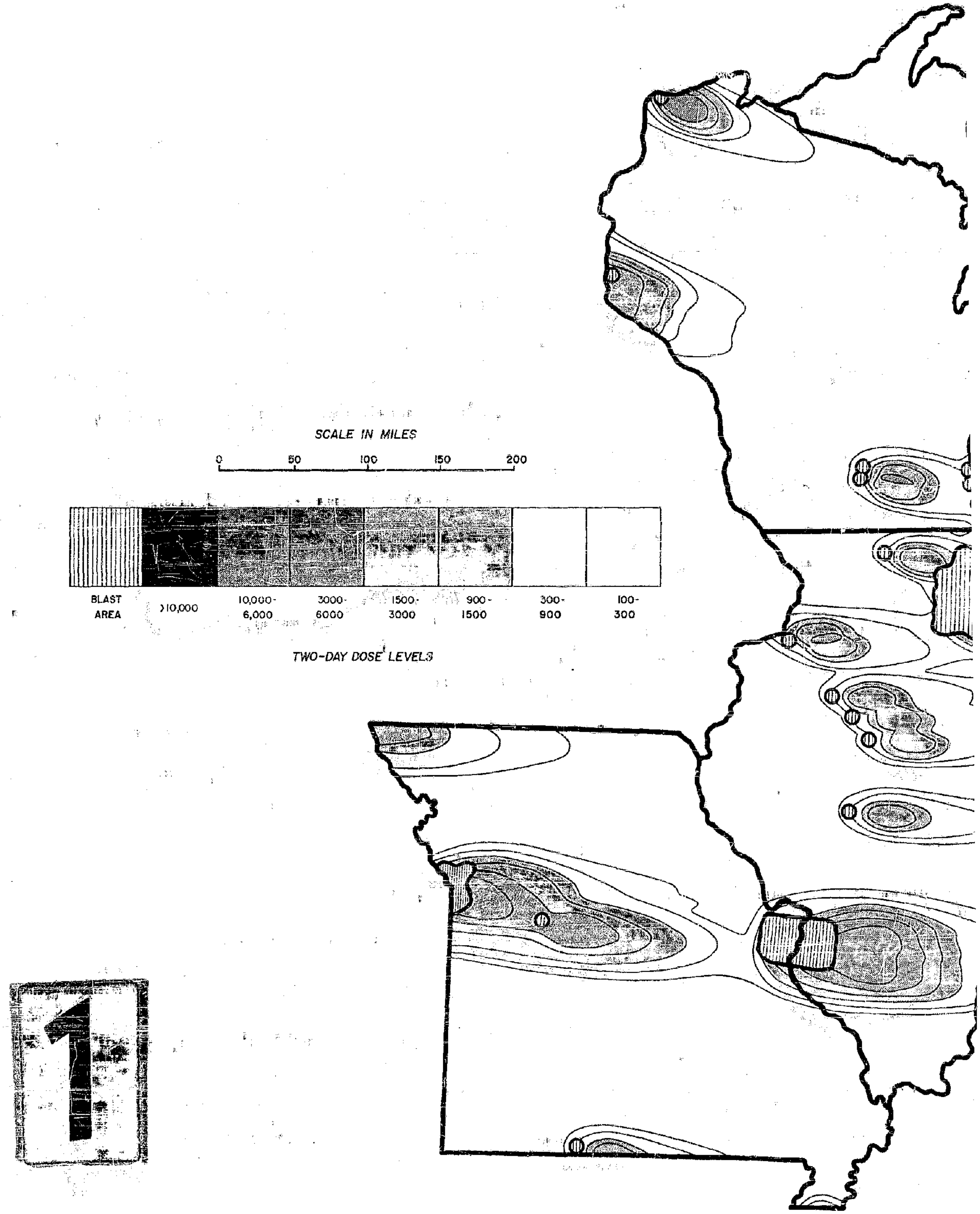


Fig. 6.9 Fallout Over Region 3 From Combined Attack in Summer

Megatons (Fission) on Military and Industrial Targets in OCDM Region 3 = 240

Megatons (Fission) on U. S. = 2720

Mean Seasonal Summer Wind


SCALE IN MILES
0
50
100
150
200
BLAST AREA
>10,000
10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS
1

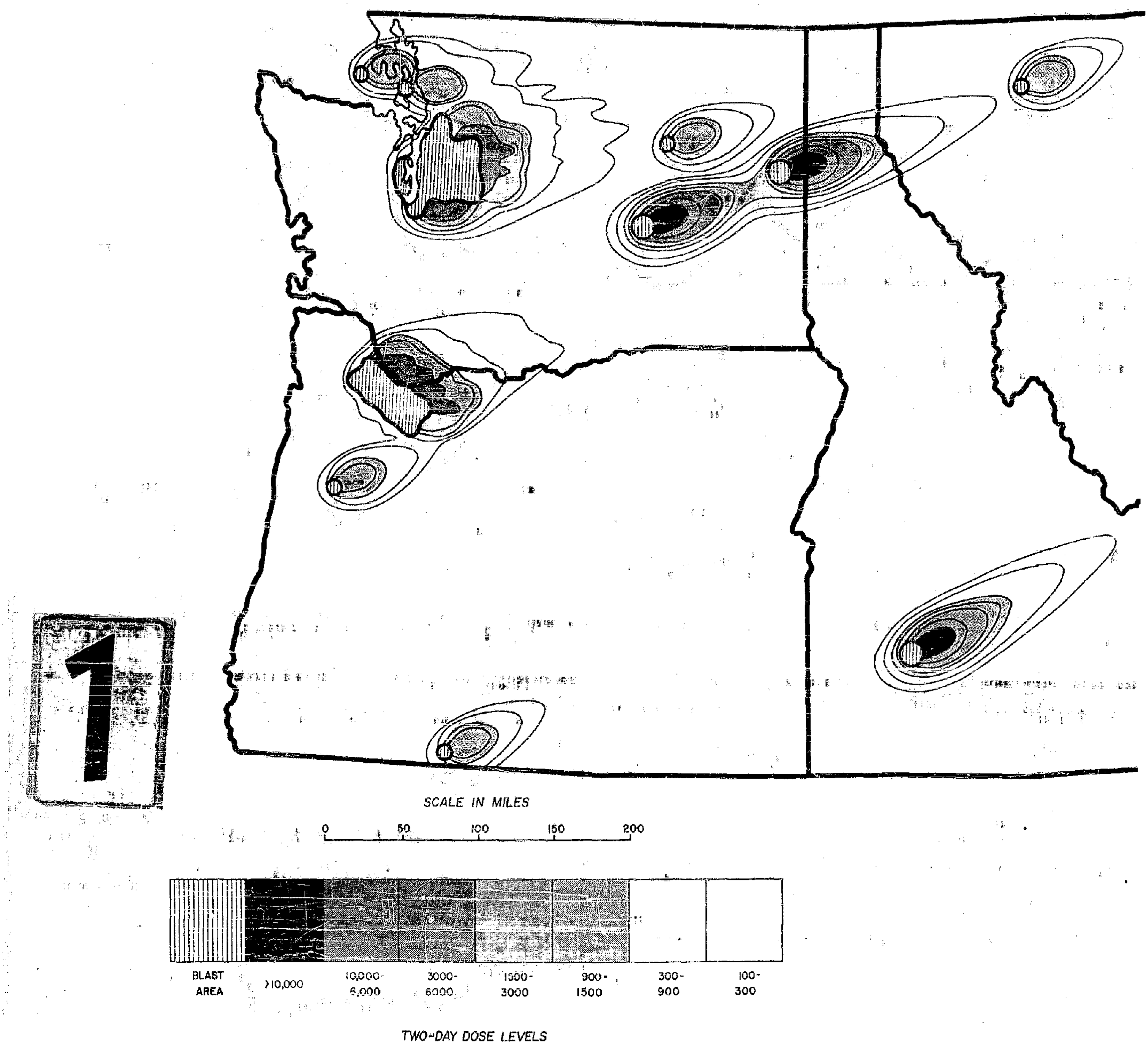
2

Fig. 6.10 Fallout Over Region 4 From Combined Attack in Summer

Megatons (Fission) on Military and Industrial Targets in OCDM Region 4 = 340

Megatons (Fission) on U. S. = 2720

Mean Seasonal Summer Wind



1
SCALE IN MILES
0
50
100
150
200
BLAST AREA
>10,000
10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS

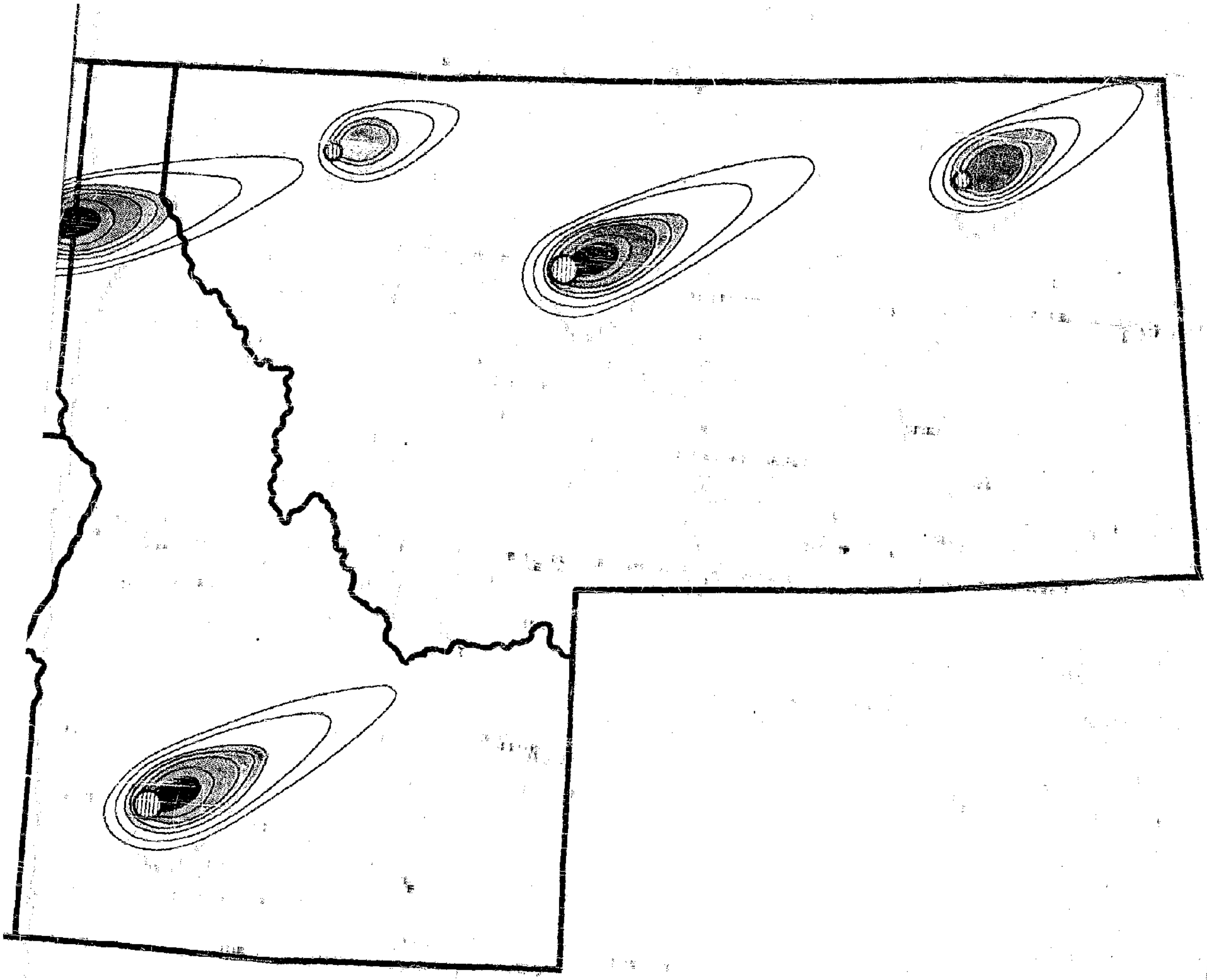


Fig. 6.11 Fallout Over Region 8 From Combined Attack in Summer

Megatons (Fission) on Military and Industrial Targets in OCDM Region 8 = 210

Megatons (Fission) on U. S. = 2720

Mean Seasonal Summer Wind

2

1

6.2 FALLOUT FROM MILITARY ATTACK

6.2.1 Winter Wind Conditions

Figures 6.12 to 6.14 illustrate the fallout situation that might result over Regions 1, 3, and 8 from an 1840-MT attack (1230 fission megatons) on our retaliatory and defense capability. Areas with greater than 6000 r 2-day dose occur downwind of the ICBM installations. Levels above 3000 r occur in other areas only when two or more targets are in line with each other with respect to the wind direction. As a result only in a relatively few areas is a shelter factor greater than 20 needed to keep the 2-day dose of the sheltered population below 100 r, and a factor of 50 is adequate for all areas other than those close to ICBM installations.

The distribution of the attack pattern with respect to the wind direction is one of the major factors in determining the per cent of the area of a region covered by fallout. In Region 8, for example, the industrial targets are coincident with or upwind of the military targets so that a 50% increase in weaponage (the combined attack as compared with the military attack) causes only a slight increase in the areas covered with fallout. The combination attack produces fallout over about 30% of the region, only slightly more than the 25% produced by the military attack.

In Region 3 a comparable situation exists both with respect to the weaponage assigned and the geographical distribution of the targets with respect to the wind. The area covered by fallout is about 50% for the combined attack and a little more than 40% for the military attack.

In Region 1, however, the more widespread distribution of industrial targets across the wind direction greatly increases the area covered by fallout. The military attack of comparable size (over a somewhat smaller area) produces fallout over about 30% of the land — a large portion of the fallout goes out to sea. The 150% increase in weaponage for the combined attack is distributed not only coincident with and upwind of most military targets, but is also located across the prevailing wind — Binghamton, northeastern New Jersey and the St. Lawrence Seaway — so that much greater areas are covered by fallout. The total effect from these crosswind targets and similar ones upwind of the region — Erie, Detroit, Toronto and Montreal — is to cover more than 75% of the region with fallout.

The location of targets in and around these three regions is such that the per cent of area covered in each case is not very sensitive to a change in wind

direction on the order of 20 degrees. A change of 90 degrees clockwise, however, would both be marked in its effect and different among the three regions. Such a change would increase the fallout area in Region 8 for both military and combined attacks. The change would decrease the fallout area in Region 1, particularly in the combined attack. The change in wind direction would have a smaller effect on the area covered in Region 3 although it would probably tend to decrease. A change of this nature is possible in Region 3 but is highly unlikely in Regions 8 and 1.

6.2.2 Summer Wind Conditions

The fallout from the 1840-MT military attack under typical summer wind conditions is shown in Figures 6.15, 6.16, and 6.17 for the same regions (Regions 1, 3, and 8) as illustrated for the winter military attack. Once again, the lower wind speed results in a smaller area being covered by 2-day dose levels of 100 to 1000 r, but due to the greater concentration of fallout near the target areas, larger areas at the higher levels were found.

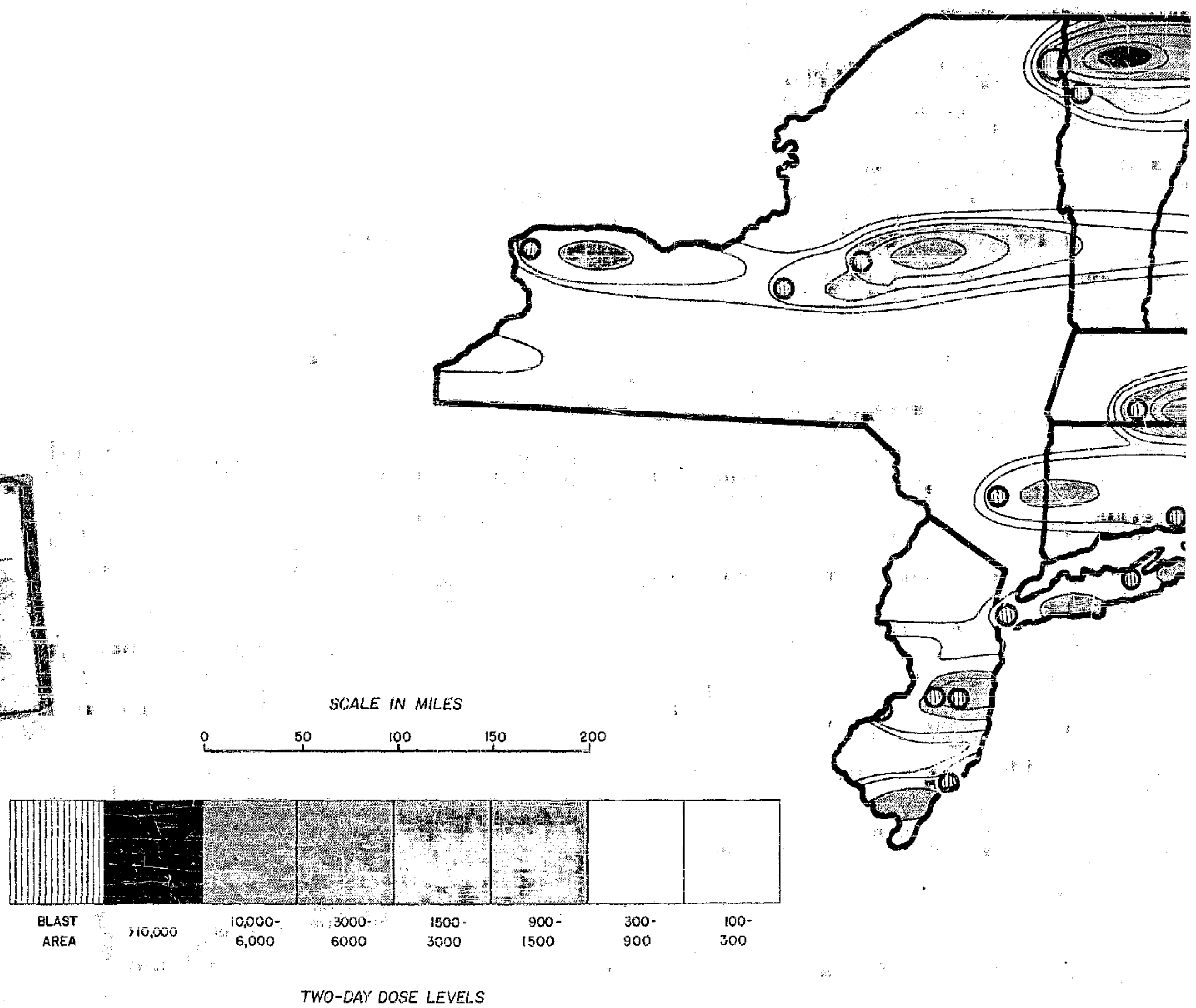
Effects from variations in the wind direction can be seen best in Region 3 (Figure 6.16) where the range of the mean seasonal wind direction varies from 40 to 160 degrees during the year. The most noticeable effect is that high levels occur around targets where none existed before. The reason for this is that a shift in the wind can cause the radiation from two or more targets to overlap where previously they covered no common ground. In those regions where large wind shifts are likely to occur, any areas which form an approximate line with two or more targets could be subjected to at least twice as much fallout as those areas which are 15 or more miles away from a straight line which is common to the several targets.

6.3 SUMMARY OF PREDICTED FALLOUT LEVELS OVER THE U. S. AND COMPARISONS WITH DIFFERENT AGENCIES

6.3.1 Comparison Between Different Countrywide Fallout Estimates

One convenient way of statistically summarizing the radiological situation over the U. S. resulting from a nuclear attack is to plot radiation intensity (or 2-day dose) against the per cent of area of the U. S. contaminated to the given intensity level or less. Such a plot for seven different attacks of which four were developed and analyzed by the RAND Corp., and three studied by OCDM, appears in reference 1 and is reproduced here as Figure 6.18. Perhaps the most striking feature of this figure is the discrepancy between the levels predicted for the modified

1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BLAST AREA
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10,000-6,000
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300-900
100-300
TWO-DAY DOSE LEVELS

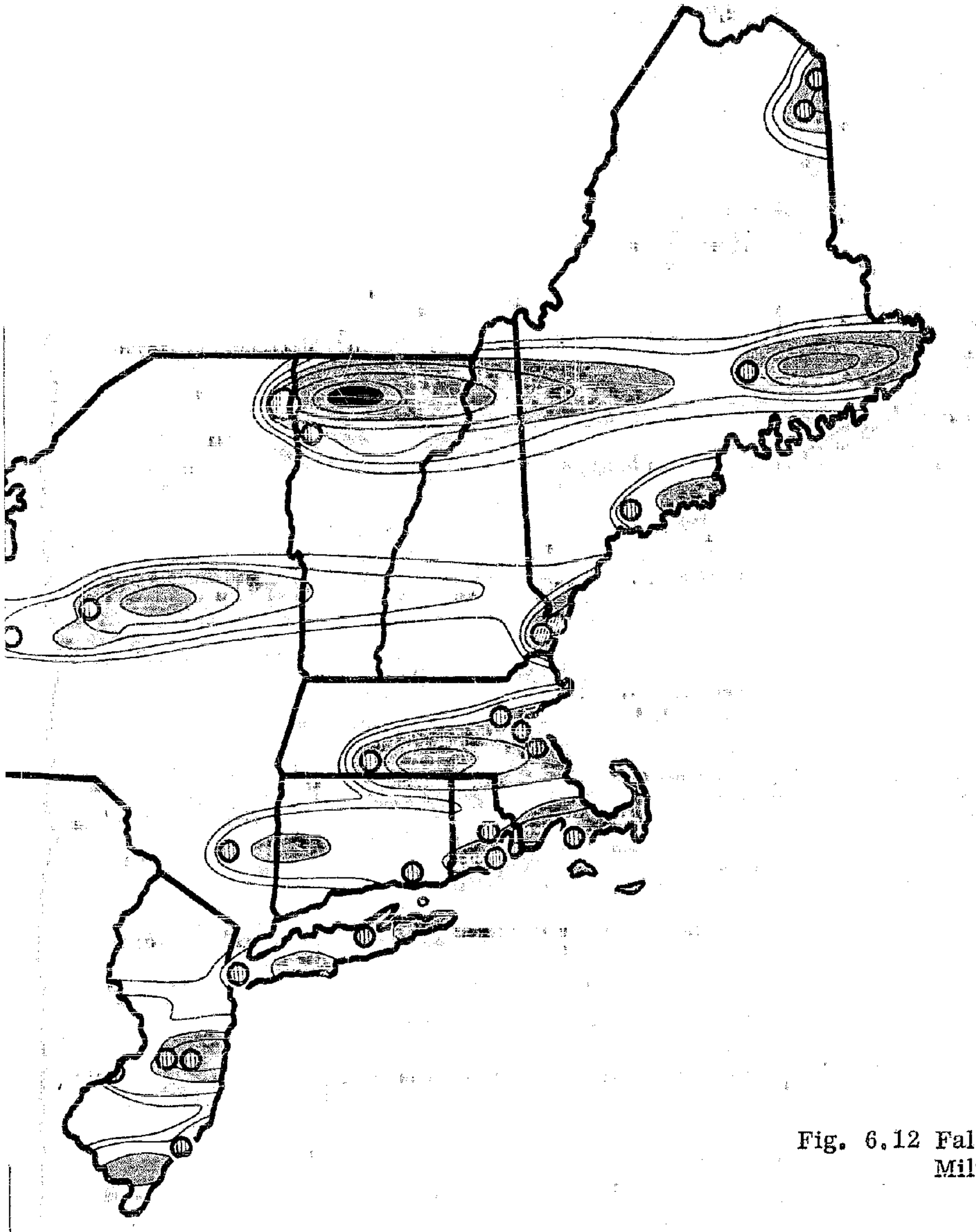


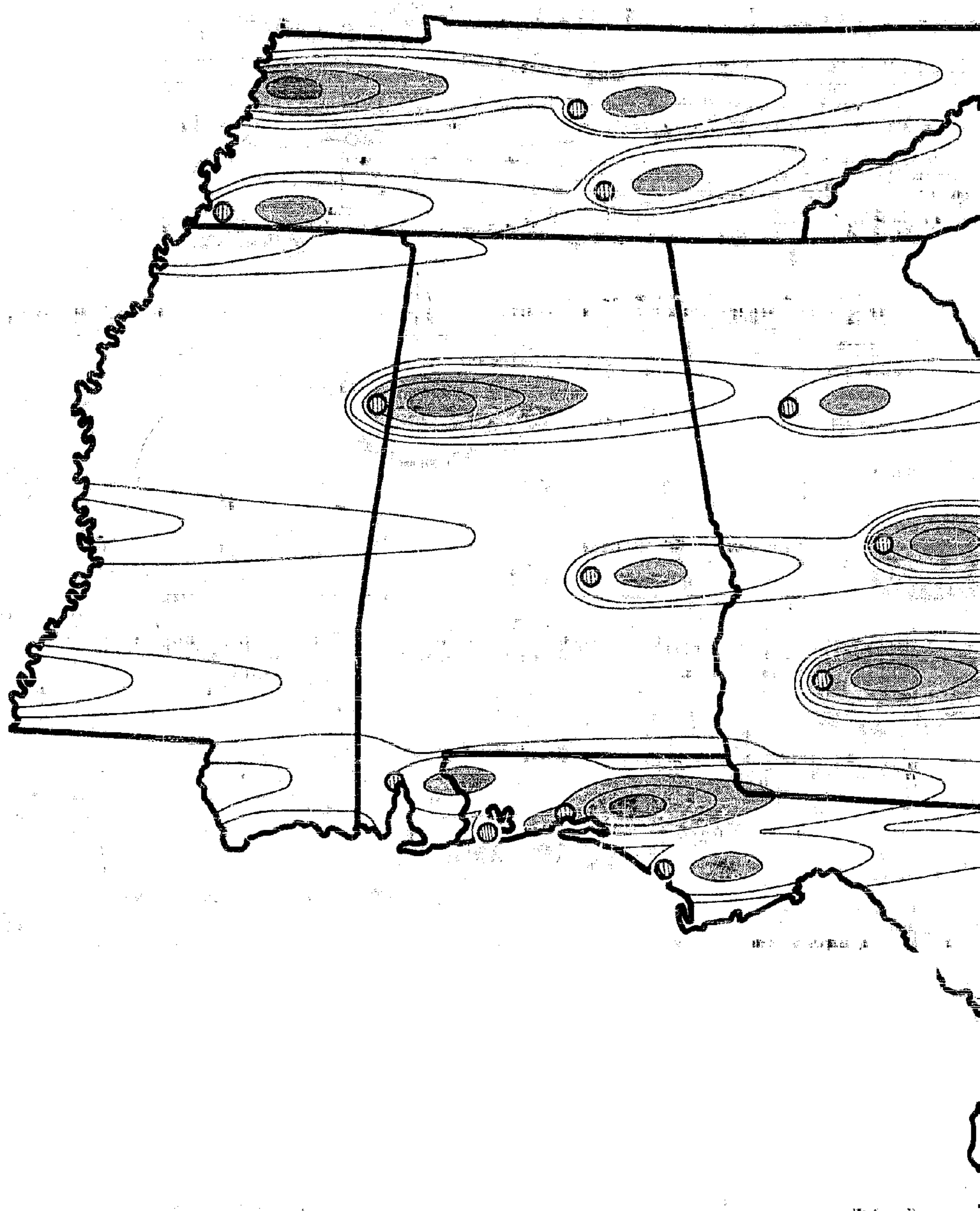
Fig. 6.12 Fallout Over Region 1 From Military Attack in Winter

Megatons (Fission) on Military Targets in OCDM Region 1 = 150

Megatons (Fission) on U. S. = 1230

Mean Seasonal Winter Wind

2



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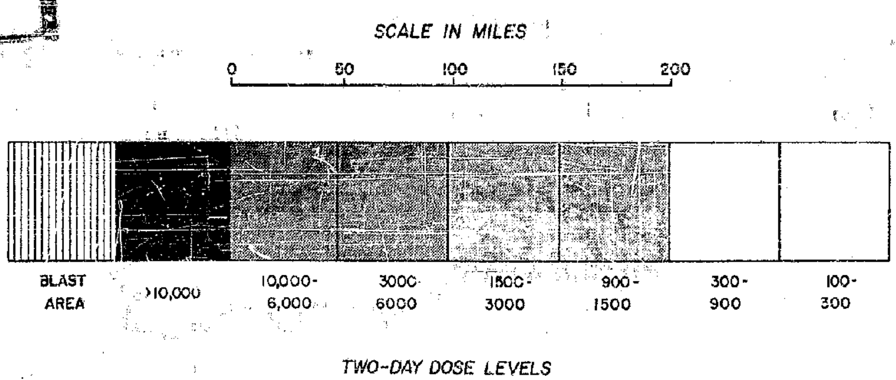

SCALE IN MILES
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BLAST AREA
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100-300
TWO-DAY DOSE LEVELS

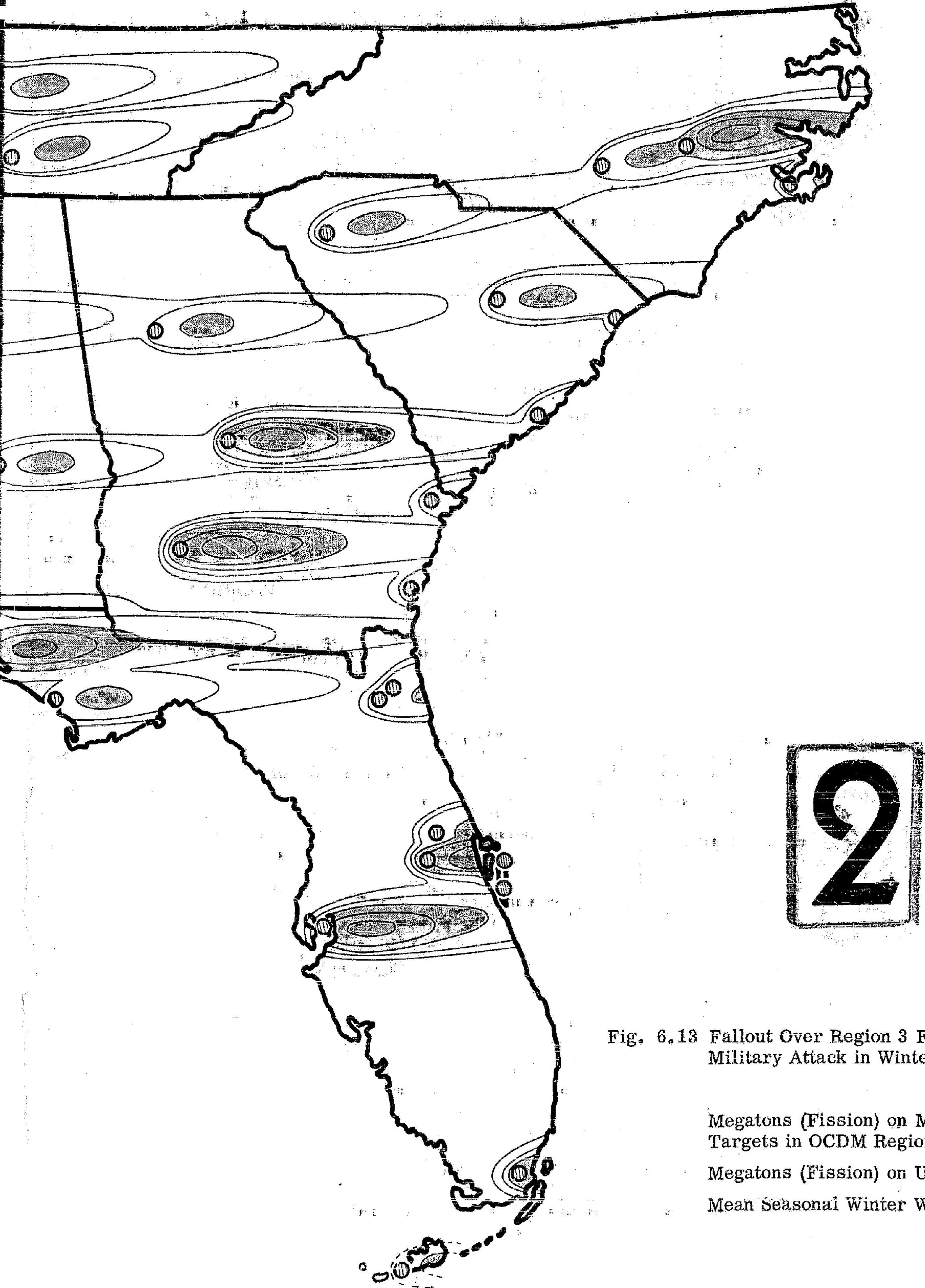
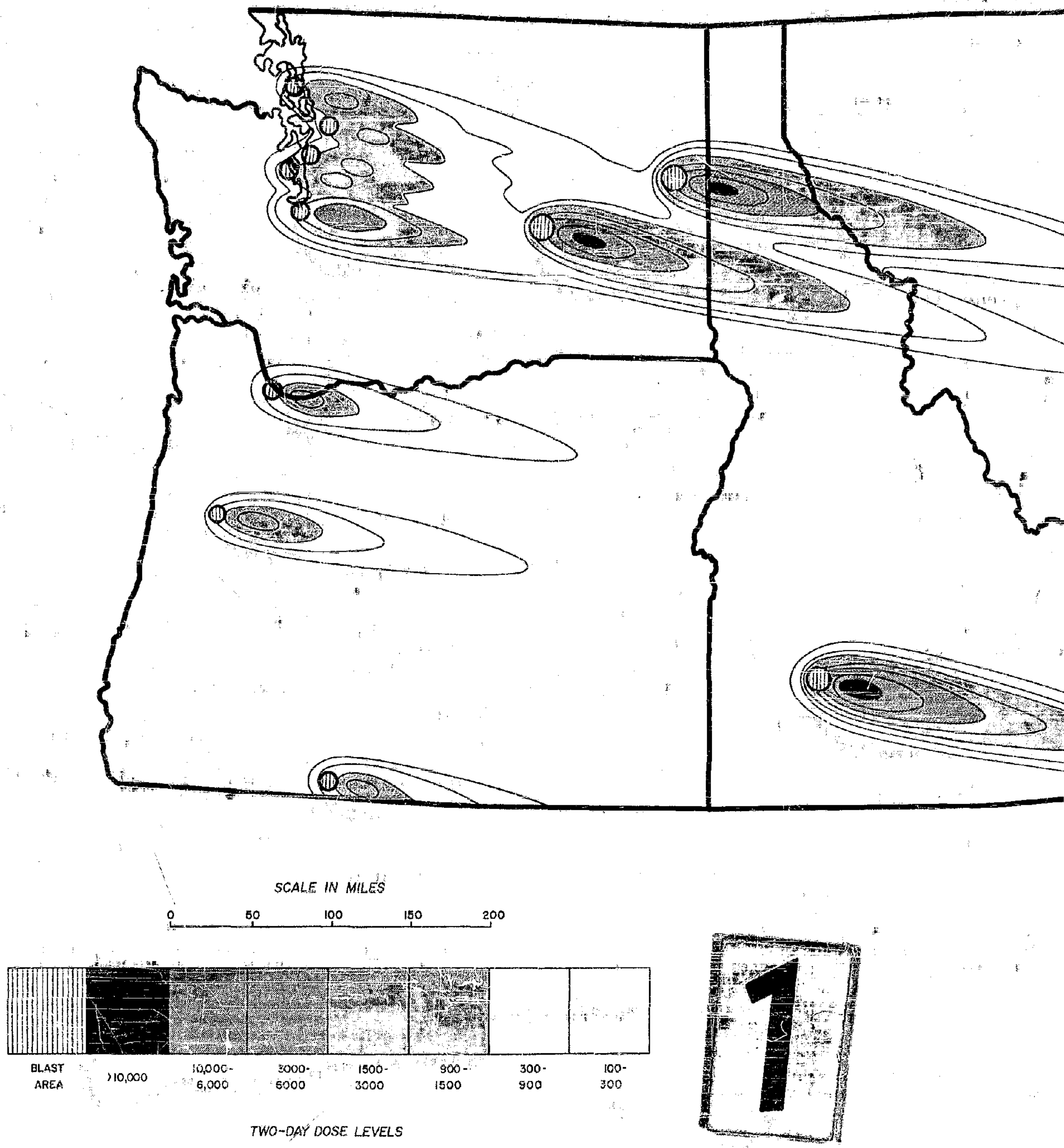


Fig. 6.13 Fallout Over Region 3 From Military Attack in Winter

Megatons (Fission) on Military Targets in OCDM Region 3 = 160

Megatons (Fission) on U. S. = 1230

Mean Seasonal Winter Wind


SCALE IN MILES
0 50 100 150 200
BLAST AREA
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10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS

1

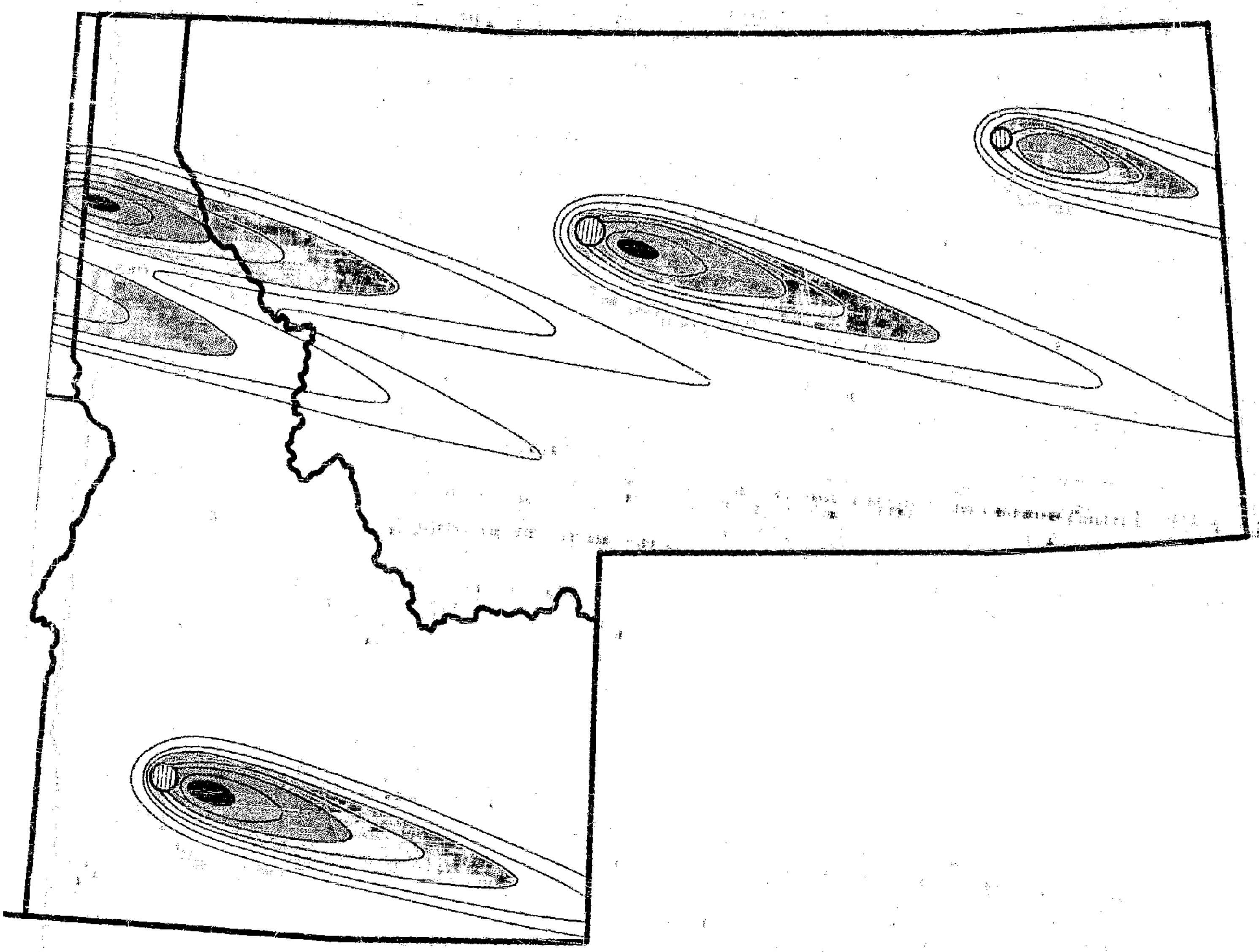


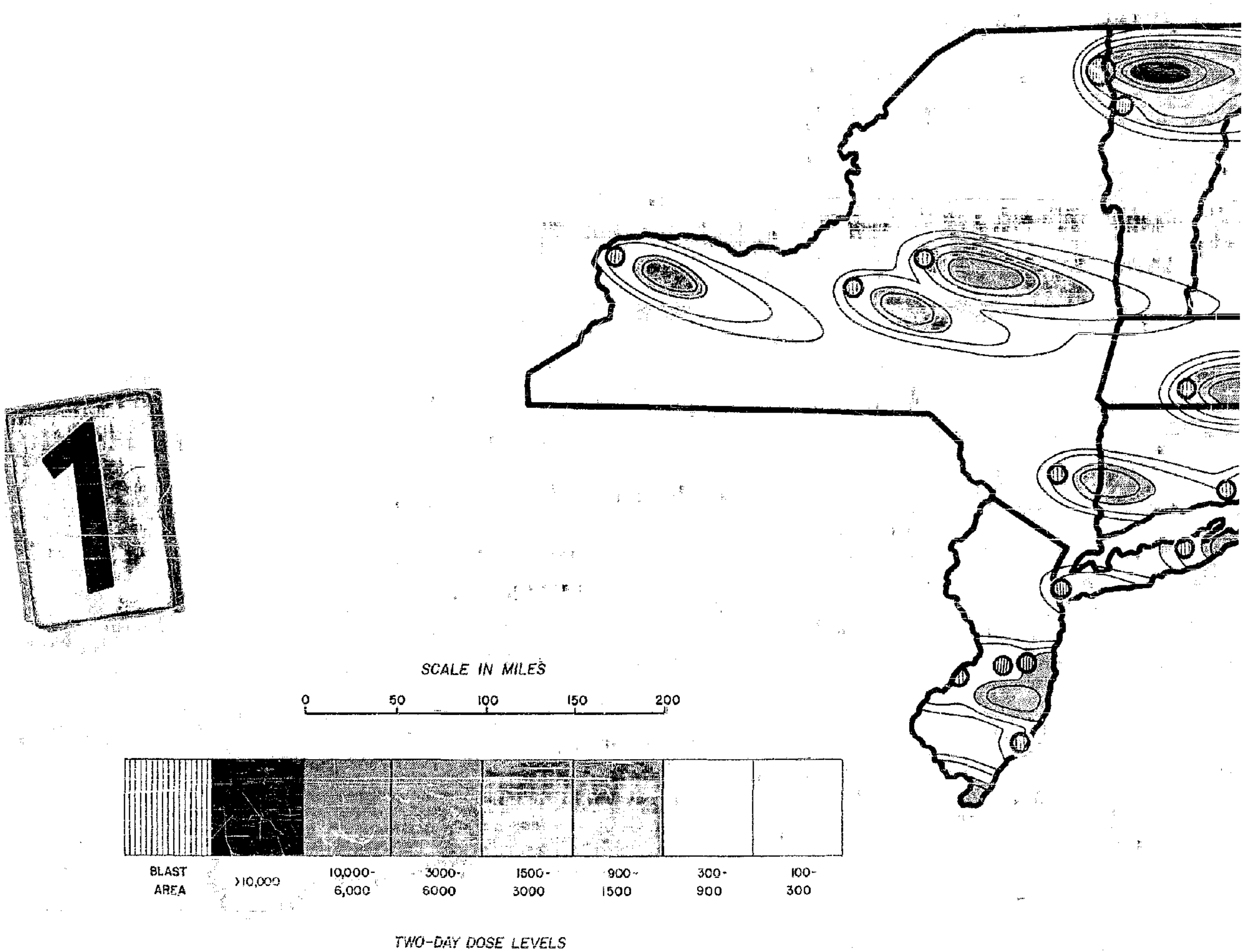
Fig. 6.14 Fallout Over Region 8 From Military Attack in Winter

Megatons (Fission) on Military Targets in OCDM Region 8 = 150

Megatons (Fission) on U. S. = 1230

Mean Seasonal Winter Wind

2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SCALE IN MILES
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50
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BLAST AREA
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10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS

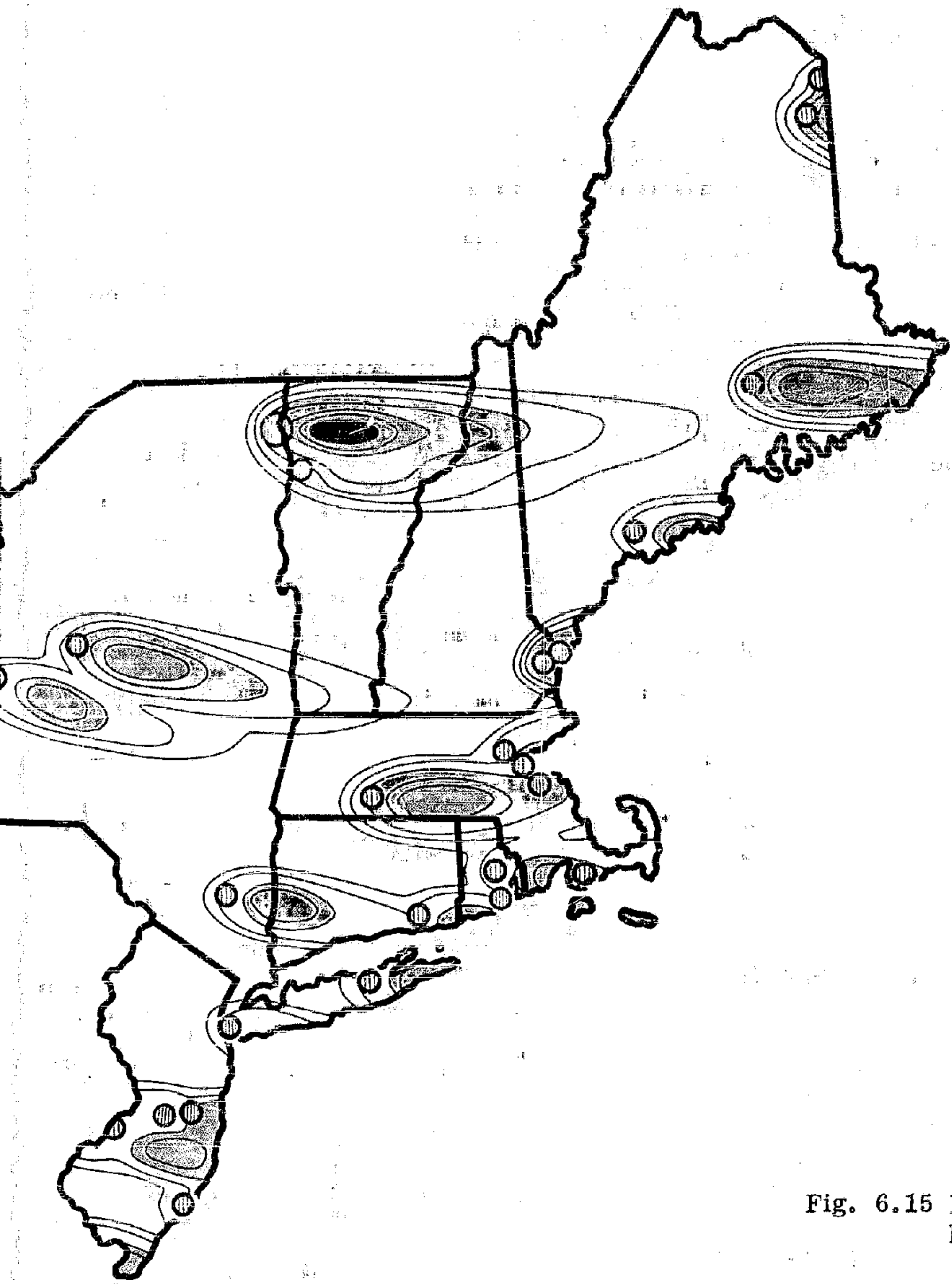


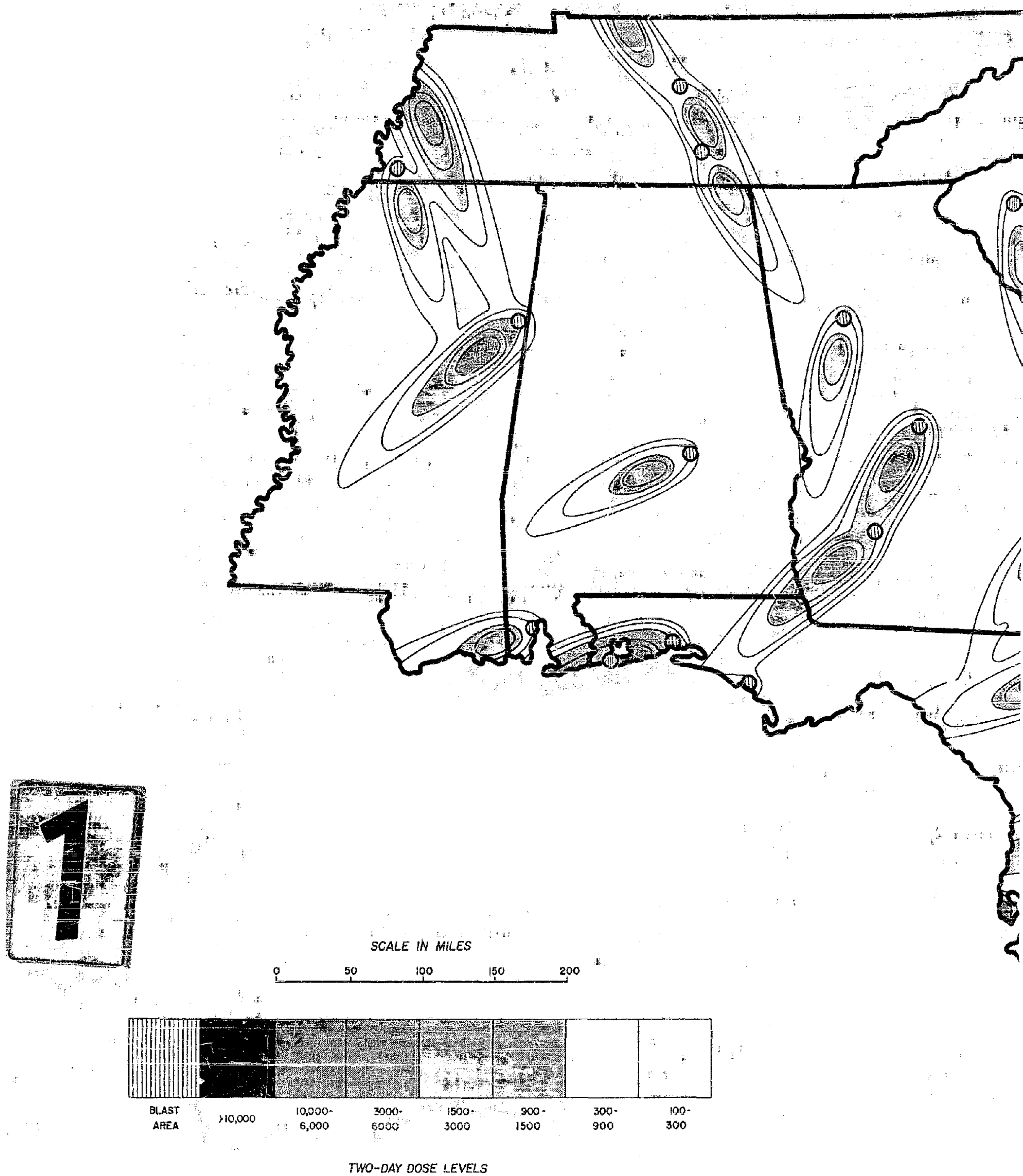
Fig. 6.15 Fallout Over Region 1 From Military Attack in Summer

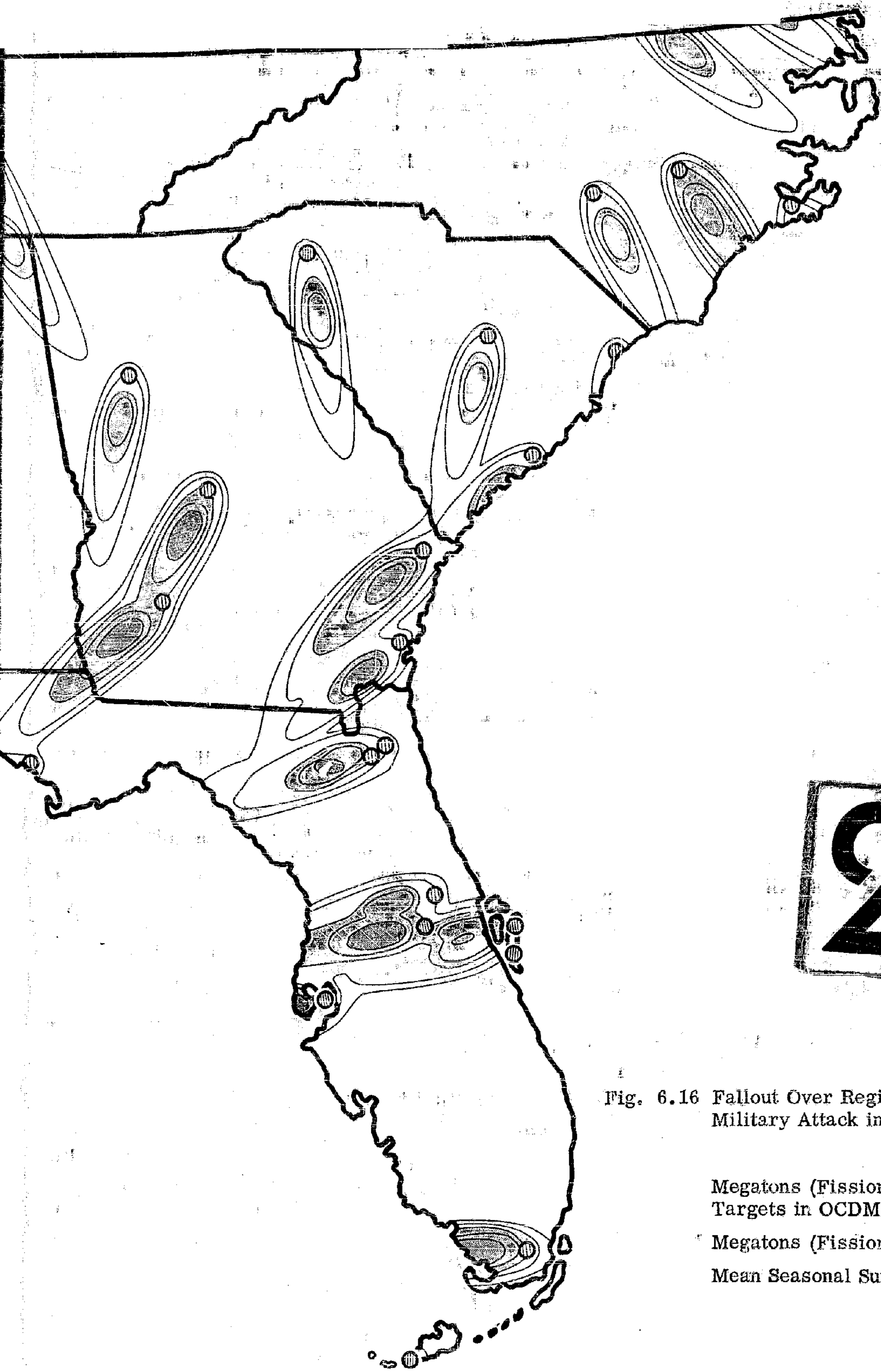
Megatons (Fission) on Military Targets in OCDM Region 1 = 150

Megatons (Fission) on U. S. = 1230

Mean Seasonal Summer Wind

2


1
SCALE IN MILES
0
50
100
150
200
BLAST AREA
>10,000
10,000-6,000
3000-6000
1500-3000
900-1500
300-900
100-300
TWO-DAY DOSE LEVELS



2

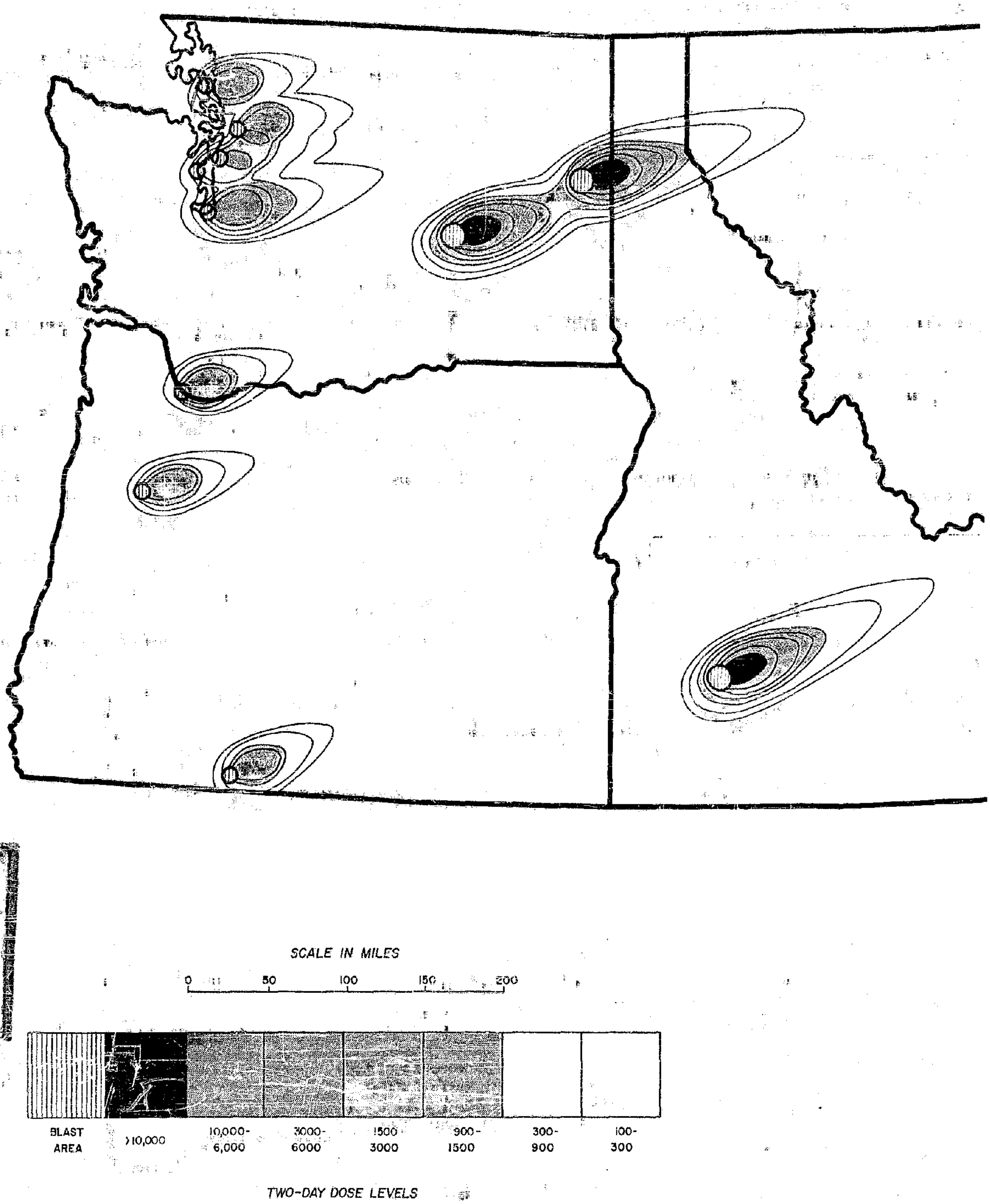
Fig. 6.16 Fallout Over Region 3 From Military Attack in Summer

Megatons (Fission) on Military Targets in OCDM Region 3 = 160

Megatons (Fission) on U. S. = 1230

Mean Seasonal Summer Wind

1


SCALE IN MILES
0
50
100
150
200
BLAST AREA
>10,000
10,000- 6,000
3000- 6000
1500 3000
900- 1500
300- 900
100- 300
TWO-DAY DOSE LEVELS

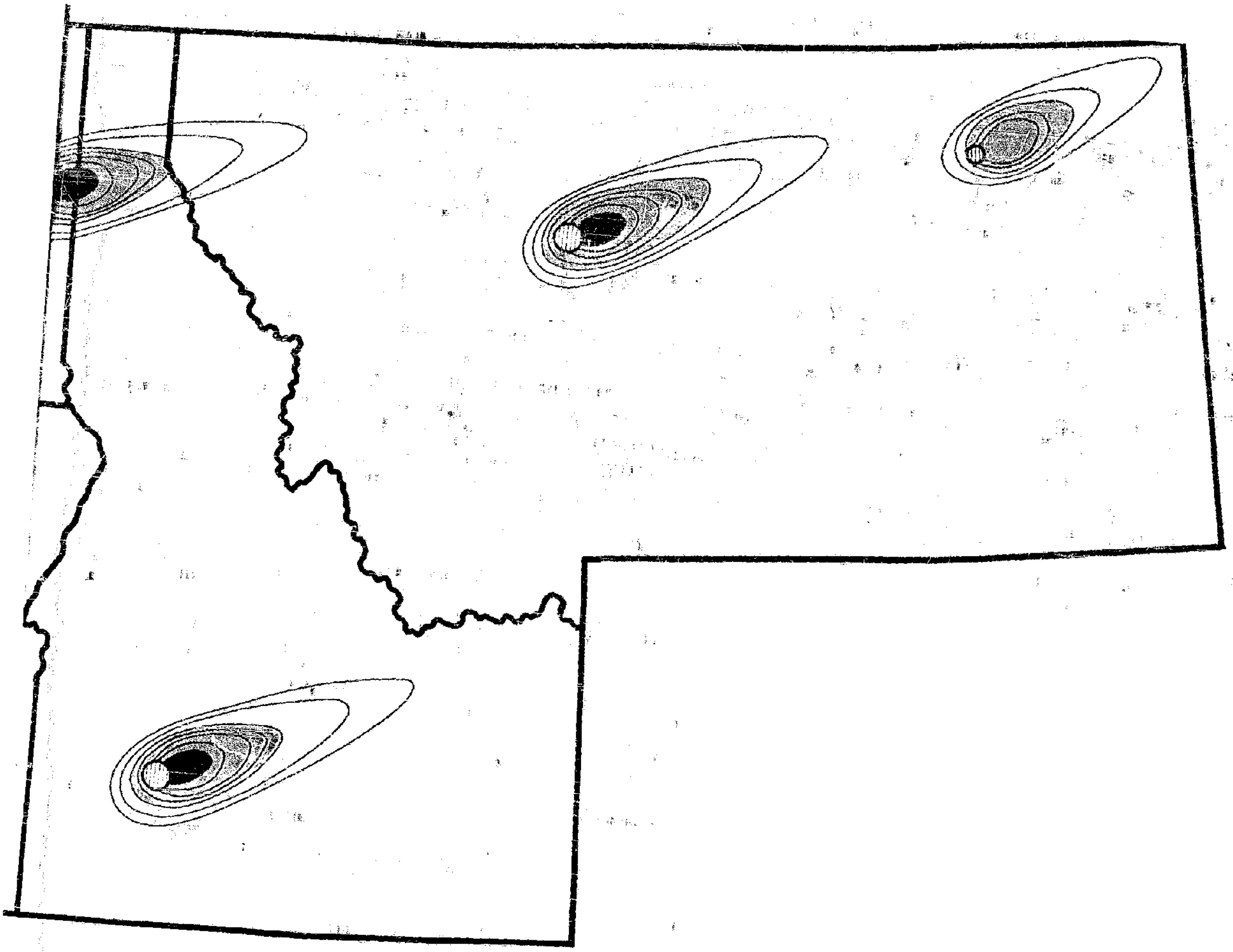


Fig. 6.17 Fallout Over Region 8 From Military Attack in Summer

Megatons (Fission) on Military Targets in OCDM Region 8 = 150

Megatons (Fission) on U. S. = 1230

Mean Seasonal Summer Wind

2

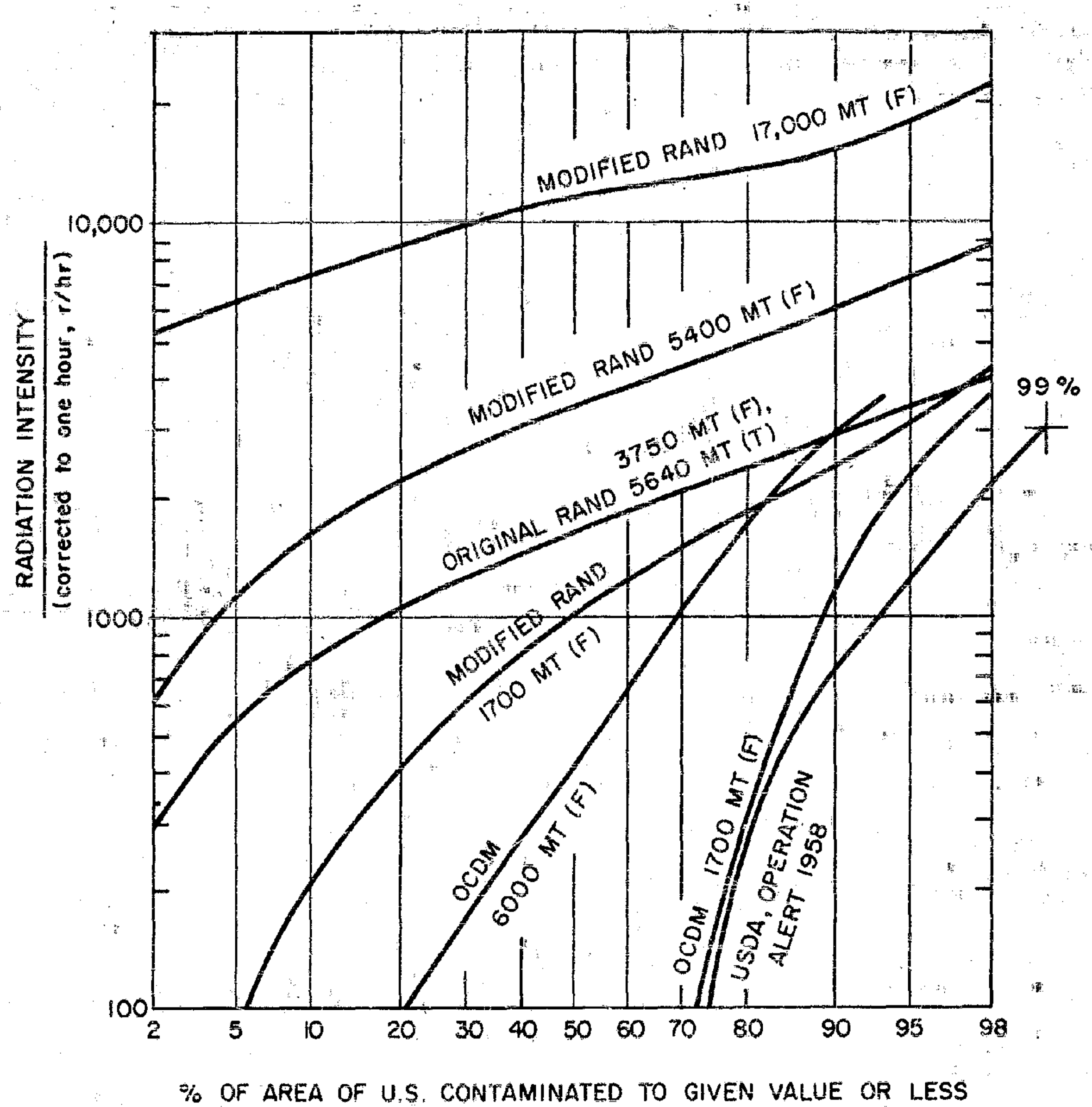


Fig. 6.18 Comparison of Various Estimates of the Radiological Situation Resulting From Different Nuclear Attacks on the U. S.

RAND 1700 fission megaton attack and those shown for the OCDM attack with the same megatonnage. For example, the RAND curve shows only 10% of the area of the U. S. contaminated to a level of 200 r/hr at H + 1, while the OCDM curve indicates that 77% of the area has less than 200 r/hr. The radiation intensity as shown by RAND, corresponding to 77% of the area, is 1800 r/hr at H + 1. The two curves do, however, approach each other at the high end — the RAND curve showing 5% of the area greater than 3100 r/hr, while OCDM predicts 2400 r/hr for the same area.

Similar curves, using 2-day dose levels instead of r/hr at H + 1, have been calculated from the figures of Sections 6.1 and 6.2 which displayed geographically the levels of fallout over the U. S. for the attack patterns developed in Chapter 2. Figure 6.19 shows the percentage of the U. S. covered to a specified 2-day dose level or less for the two levels of attack studied and for both winter and summer mean wind conditions. It is interesting to note that in the case of the summer winds, which are lower in speed, the areas covered to levels below 1000 r, 2-day dose are less than those for the winter winds, but above this level the areas are greater than for the winter wind condition.

For the 4080-MT attack (2720 fission megatons), only 2% of the land area had more than a 10,000 r 2-day dose under the summer wind condition or more than 8000 r under winter wind conditions. Half the land area was covered to less than 125 r 2-day dose in winter, while almost two-thirds of the area was less than this level when the summer wind was used. The 1840-MT military attack (1230 fission megatons) produced 2-day dose levels in excess of 2500 r over only 2% of the U. S., while 80% of the area gave a value of 250 r or less in winter and 50 r or less in the summer.

Although this statistical picture of the country as a whole is most interesting, each OCDM region (and perhaps each state) will want to know how they might stand relative to the over-all situation. Figure 6.20 shows the results for Regions 1 and 2 taken together, as well as Region 5, and Region 7. The 2720 fission megaton combined attack under winter wind conditions was used for this comparison. As was expected, Regions 1 and 2 were the worst off with some 10% of the area covered to a 3000 r, 2-day dose or greater, and half the area over 500 r. The 10% points for Regions 5 and 7 are 1800 r and 1300 r respectively, while only 40% of Region 5 and 25% of Region 7 were found to have more than a 100 r 2-day dose.

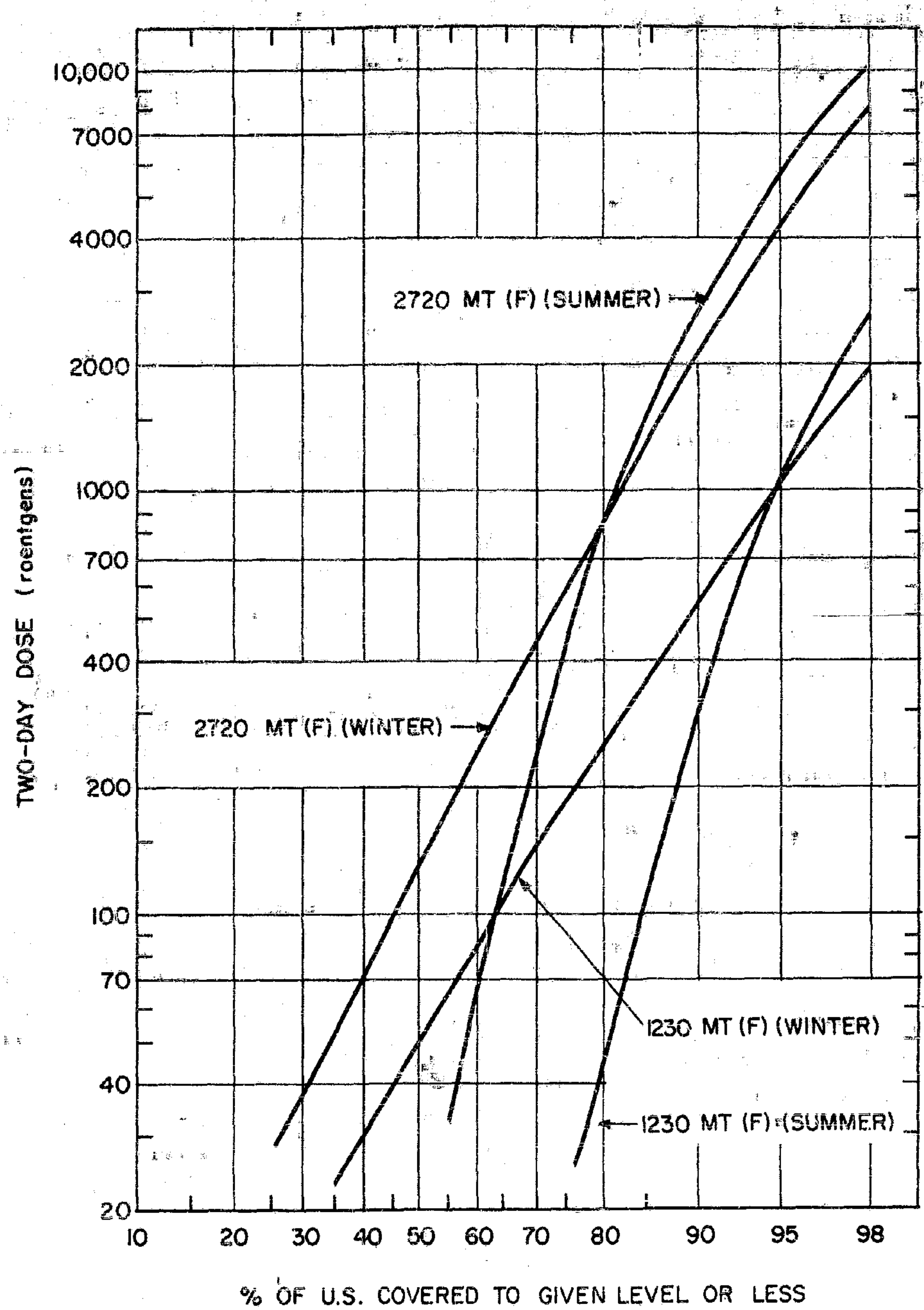


Fig. 6.19 Per Cent of Area of U. S. Covered to Given 2-Day Dose Levels For Two Different Attack and Wind Conditions

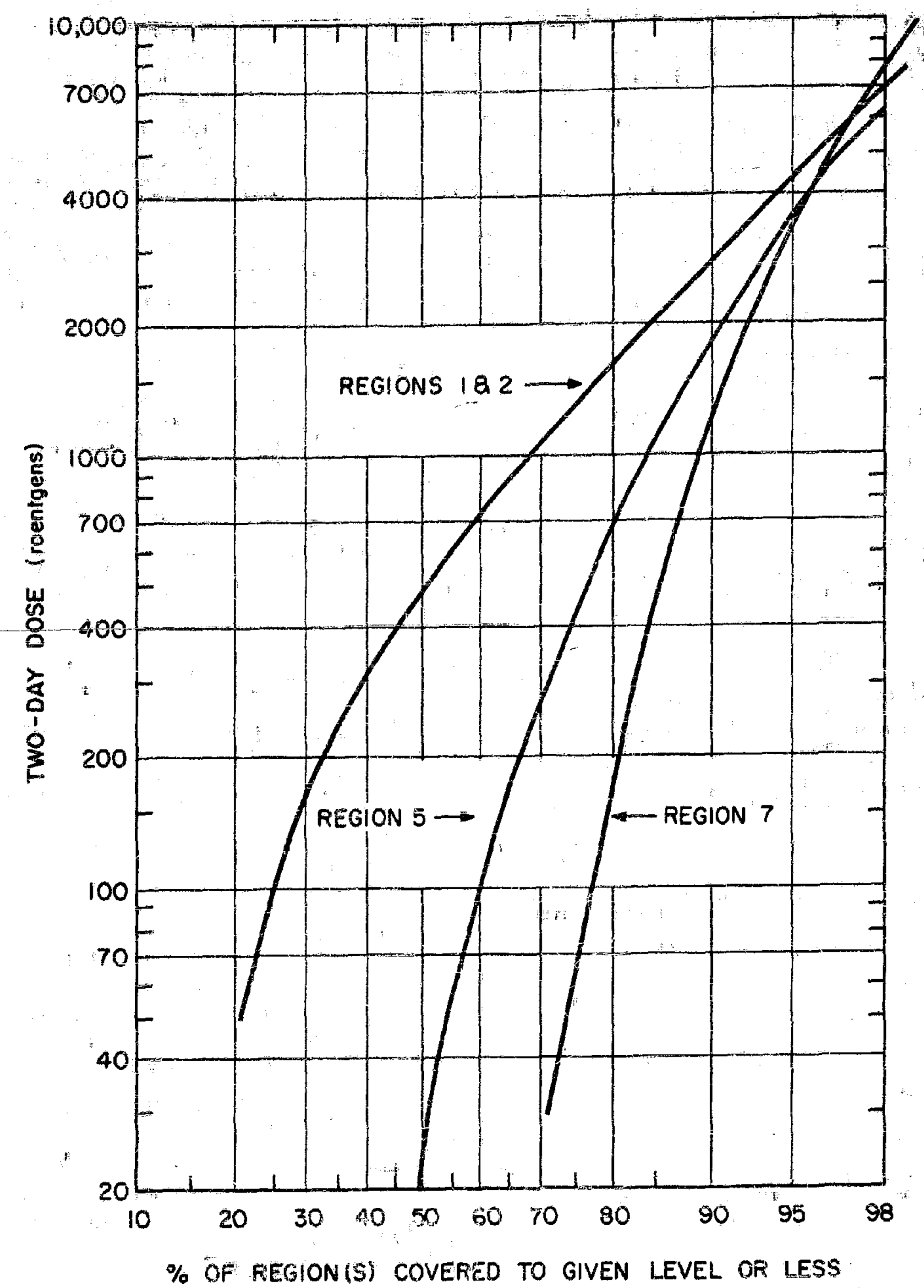


Fig. 6.20 Per Cent of Area of Different OCDM Regions Covered to Given 2-Day Dose Levels For a 2720-MT (F) Attack and Winter Wind Conditions

6.3.2 Statistical Comparison of Average Fallout Levels Over the U. S.

As was pointed out from observations of Figure 6.18 at the beginning of the previous section, a wide discrepancy exists between the various estimates of the radiological situation resulting from a countrywide nuclear attack. To see whether these differences were due primarily to the distribution of fallout rather than the total amount of fallout associated with a given level of attack, the cumulative probability distribution curves shown in Figure 6.18 were first graphically differentiated to obtain the corresponding probability density functions which are shown in Figure 6.21. The cell widths are equal to the factor $\sqrt{2}$.

A most interesting feature of this figure is the fact that the RAND curves have a rather sharp pronounced maximum indicating much larger areas covered to a given level than to higher or lower levels, while the OCDM curves imply that the amount of area covered to the different intensity levels over a very broad range – from, say, 40 r/hr to 4000 r/hr – is almost invariant. There seems to be no obvious explanation for this difference.

The first moment of these density distributions defines the average radiation intensity over the U. S. in each case. These values were calculated and are given in Table 6.1.

TABLE 6.1

COMPARISON OF AVERAGE FALLOUT LEVELS OVER THE UNITED STATES

Fallout model	Level of attack (fission megatons)	Kilotons per sq. mile over the U.S.*	Ave. r/hr over U.S. at H + 1	r/hr per KT/sq. mile
1. OCDM	1700.	.567	357	630
2. RAND (modified)	1700	.567	1251	2200
3. RAND (original)	3750	1.25	1778	1420
4. RAND (modified)	5400	1.8	3668	2040
5. OCDM	6000	2.0	1031	515

* The area of the U. S. is approximately 3×10^6 sq. miles.

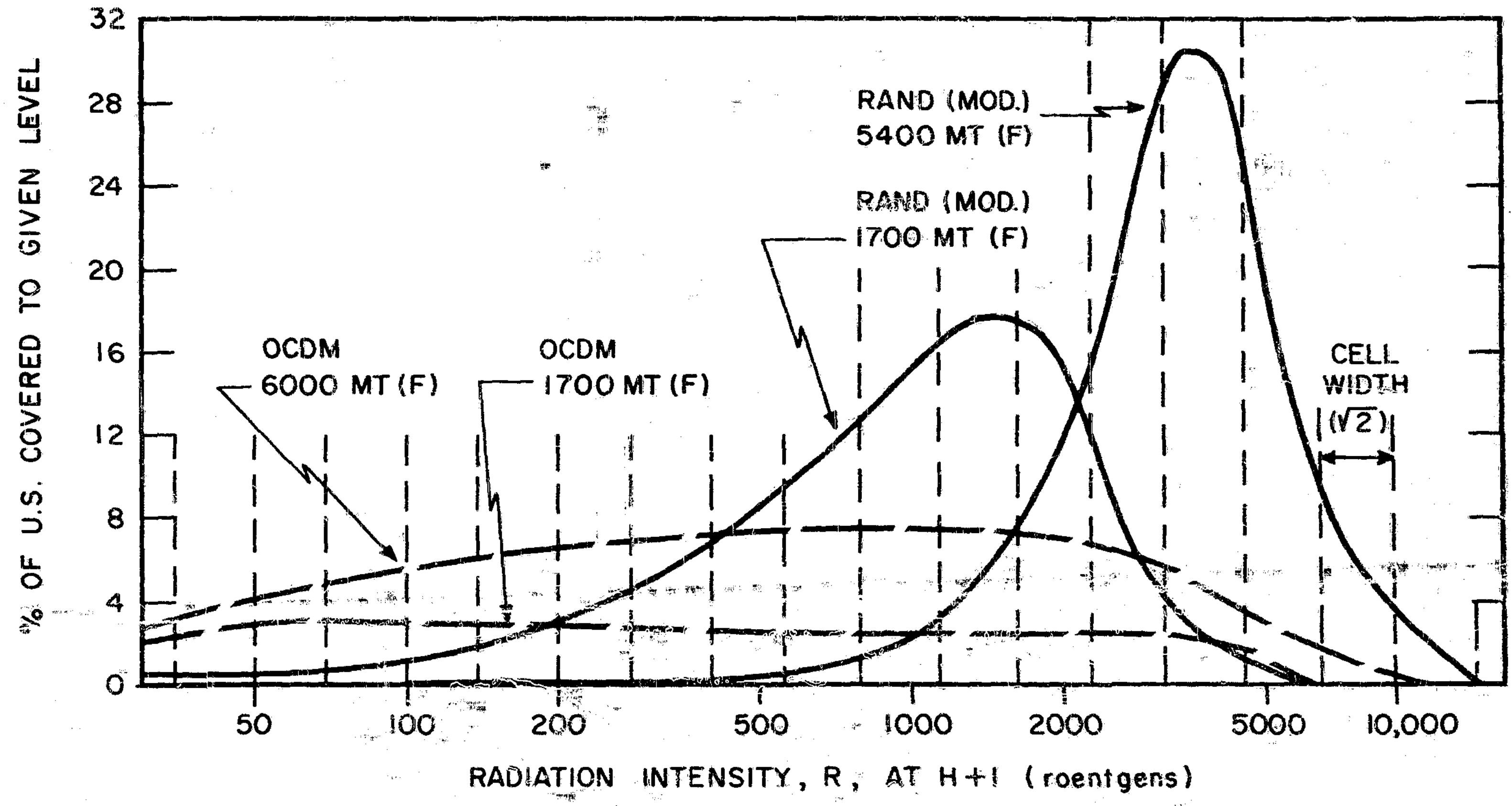


Fig. 6.21 Per Cent of U. S. Covered to Given Radiation Levels For Different Attacks

From this table we see that the modified RAND fallout model produces about 2100 r/hr per KT/sq. mile, the original RAND model, about 1400 r/hr per KT/sq. mile, while the corresponding OCDM figure is only around 575. In other words, it would appear that the modified RAND fallout model produces more than 3-1/2 times as much fallout as the model used by OCDM.

According to an article by Ralph Lapp in "The Bulletin for Atomic Scientists"* there are at least two reputable sources which have published values for the conversion factor relating kilotons of fission energy per square mile to roentgens per hour at one hour, three feet above an infinite plane. These two sources and their respective conversion factors are:

Source	Conversion Factor (r/hr for 1 KT/sq. mile)
1. Effects of Nuclear Weapons	1250
2. Bolles and Ballou, Miller and Loeb	3500

Lapp feels that these values represent lower and upper bounds, and arbitrarily selected a value of 2000 r/hr per KT/sq. mi. for use in a later article in the same magazine.

Comparing these numbers with those in the last column of Table 6.1, it appears that the modified RAND model uses a conversion factor very near 2000 r/hr per KT/sq. mi., while the original RAND model probably used a factor only slightly above the 1250 r/hr per KT/sq. mi. figure. The OCDM conversion factor appears to be only about half the 1250 figure. However, these conversion factors are idealized in that they do not take into account any reduction in the dose rate due to ground roughness. The RAND fallout model does not include a ground roughness factor, and it is not known whether the OCDM model incorporates such a factor. If it does, and that factor is in the order of 0.50, it could logically explain the effective conversion factor of only 500-600 r/hr per KT/sq. mi. Another factor which tends to lower the average radiation intensity over the country is that due to the prevailing winds, a significant part of the fallout from targets along the east coast falls over the Atlantic Ocean, and hence doesn't contribute to the predicted land dose.

* Lapp, R. E., "Local Fallout Radioactivity", Bulletin for Atomic Scientists, 15, 181-186, May 1959.

Although the results from the 2-day dose statistical su[illegible] in Figure 6.19 cannot be compared directly with the RAND and OCD [illegible] shown in Figure 6.18, since these latter represent r/hr at H + 1 areas [illegible] 2-day dose areas, the average 2-day dose for the 2720-MT(F) attack over [illegible] was calculated and found to be about 800 r. If the bulk of the fallout wer[e] [illegible] down in roughly an hour, then this figure of 800 r would correspond [illegible] 325 r/hr at H + 1, or only 360 r/hr per KT/sq. mi. The ideal co[nversion] facto[r] used in the Tech/Ops fallout model, however, is known to be 1580 [illegible] per KT/sq. [mi.] and the ground roughness factor taken to be 0.55, giving an effec[tive] [c]onversion fa[ctor] of 870 r/hr per KT/sq. mi. There are at least three reasons to ac[count] for the dif-ference between the actual conversion factor of 870 used in the mod[el] and the value of 360 implied from the fallout analysis:

1) As mentioned previously, a significant fraction of [the] east co[ast] fallout comes down over water due to the prevailing winds.

2) A significant amount of the total fallout doesn't arrive at one hour after the burst, hence the hypothetical value for r/hr at H + 1 should be increased to something more than 0.4 [t]imes the pre-dicted average 2-day dose.

3) Fallout in the immediate blast areas was not added into the total, and although the total area involved is very small in comparison to the U. S., the fallout levels in these completely damaged areas are extremely high and would have a marked effect on the over-all average for the U. S.

It is believed that these three conditions could easily reduce th[e] effective conversion factor by at least a factor of two, and hence adequately explain the implied value of 360 r/hr per KT/sq. mile.

In summary, the basic underlying factors which account for the rather [illegible] between the different countrywide radiological situa-tions have been uncovered and quanti[tatively] studied. [illegible] finding more precise values for the [ideal] conversion factor and the ground roughn[ess] factor would go a long way toward cle[ar]ing up much of the [illegible] between the [illegible] of the [r]adiological situation that have been made to date.